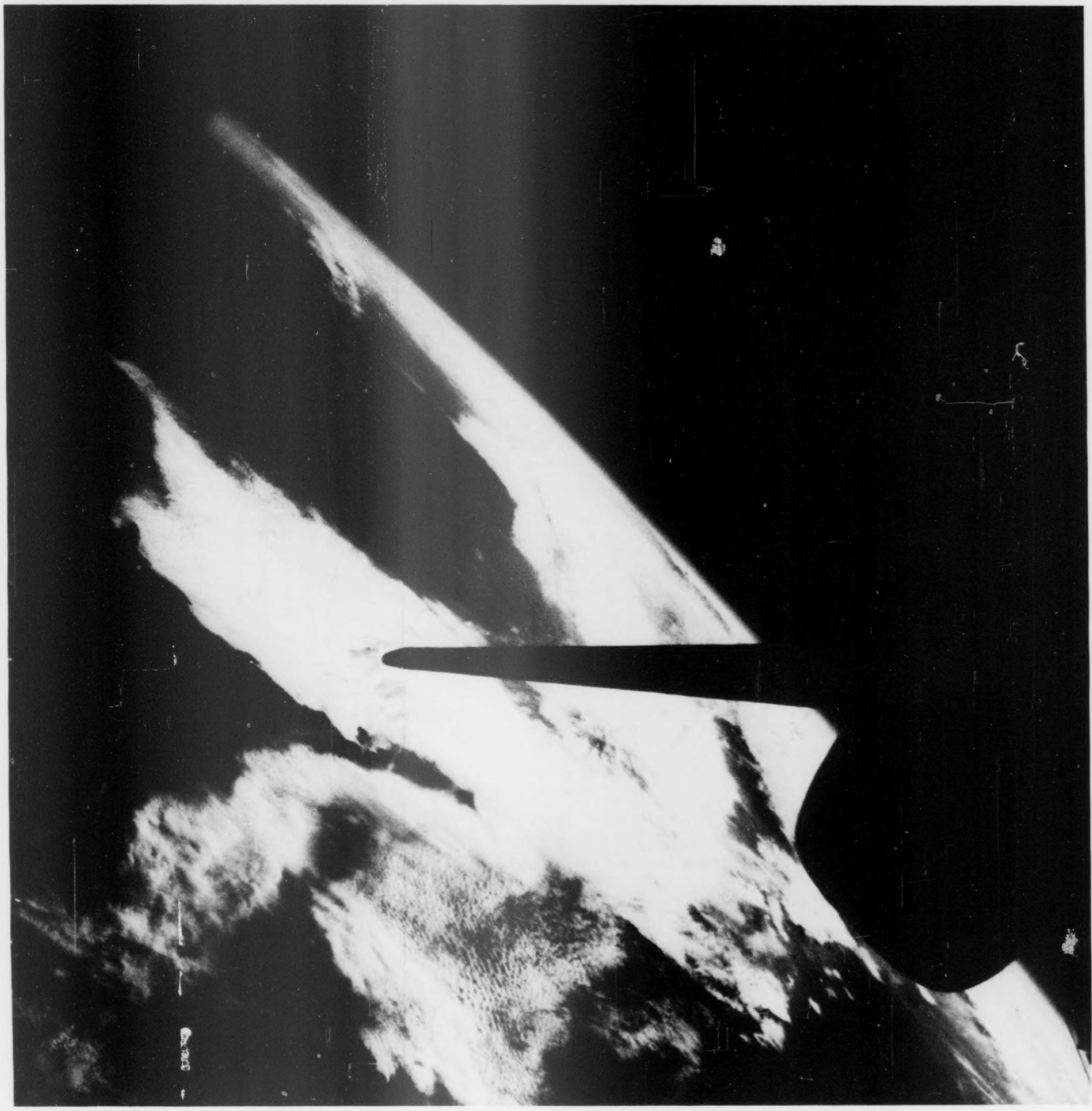
Air & Space

Vol. 6, No. 4 Summer 1983

National Air & Space Museum
Smithsonian Institution



Different Views—Observation

Air & Space
National Air and Space Museum
Walter J. Boyne, *Director*

Education Services Division
Janet K. Wolfe, *Chief*

Air & Space
Linda S. DuBro, *Managing Editor*
Holly Haynes, *Design and layout*

Air & Space, a mini-magazine for educators, is published four times during the school year as an outreach of the National Air and Space Museum, Smithsonian Institution, Washington, D.C.

Air & Space combines information from many sources for a condensed overview of the history, science, technology, and social impact of selected aviation and space subjects.

Air & Space
Address all communications to: *Air & Space*, Room P-700, Education Services Division, National Air and Space Museum, Smithsonian Institution, Washington, D.C. 20560. For changes or corrections of address, write to *Air & Space* at the above address, and include the 6-digit subscription number on your mailing label.

There is no charge for *Air & Space*. The magazine is not available by paid subscription.

Commercial interests and other publications wishing to reprint material should mail requests to the above address.

For brevity, the National Air and Space Museum is often referred to in these pages as NASM. The National Aeronautics and Space Administration is NASA.

Photos on: the cover and pp. 9-11, 16 (bottom): Courtesy NASA; pp. 7-8: Courtesy Dino Brugioni, Department of Defense Photo; p. 12: Courtesy Geoffrey Chester; p. 14 (top): From Charles G. Abbott's The Earth and the Stars; *p. 14 (bottom): Courtesy Princeton University Observatory; p. 13: From Galileo Galilei's* Delle Macchie Solari; *p. 15: Courtesy the Wheelwright Museum; p. 16 (top): Courtesy Von Del Chamberlain; p. 17 (left): Courtesy Astronomy Magazine; p. 17 (right): Courtesy The Cerro Tololo Inter-American Observatory, ©1978 The AURA, Inc.; drawings on pp. 4-6: Courtesy Frank Kingston Smith; pp. 3, 5: Courtesy NASM.*

Cover Photo: This picture of the Earth serves as a backdrop for the silhouetted Space Shuttle orbiter Columbia*'s vertical stabilizer and two orbital maneuvering system (OMS) pods at the right portion of the frame. The frame was exposed with a 70mm hand-held camera from inside the flight deck as the STS-1 crewmembers were looking through the aft window.*

Briefing

Walter J. Boyne
Director, NASM

The fascination of viewing the Sun and the heavens extends to every person and every culture in such a matter-of-fact way that we rarely consider it. No matter what a person's beliefs are, whether one is a creationist, an evolutionist, or an animist, there is common ground found in the inspiration of observing our celestial companions.

Curiously, the occurrence of this fascination with the heavens in all cultures, and in all manifestations of those cultures, never becomes obvious or boring. Each human being happily responds to a glorious sunrise or with despair to, as Snoopy would say, "a dark and stormy night." Neither poets, songwriters, advertisers, nor children ever feel that they are unimaginative or repetitive if they continually draw upon heavenly signs or analogies to make a point.

Besides the basic human psychological reasons for this, I believe in all our lives there are certain times when there is a practical reinforcement of our dependence upon the heavens that proves to us just how similar we are to our ancestors. Before navigation became so precisely oriented with its current inertial guidance systems and with its information relayed by the satellites—those man-made celestial devices—long overwater flights were made primarily by means of celestial navigation, using a sextant and the Sun and the stars to establish position.

There is no more blessed feeling than, after having flown for several hours in poor weather, over the ocean, and out of radio contact, to suddenly have the clouds part and the Sun or the stars made available for a quick shot with the sextant. During that moment when the star is collimated in the sextant, when you are viewing a point of light that belongs to a familiar constellation, you get a sense of a direct link with nature. Then, if you are lucky, the figures you derive from the shot are consoling, and you can report with confidence (but always with nonchalance) where you are. It is no less consoling when one is lost driving around an unfamiliar countryside, unsure of whether one is going north or south, to suddenly note the Sun's position and be aware of which direction to drive to reach a familiar landmark.

NASM is creating an exhibition on the concepts of the Sun, the stars, and the universe. It is extraordinarily difficult to secure a sense of human immediacy and familiarity with these awesome concepts. One section of the exhibition covers astrology, once considered a science in the West, it is still considered so in many parts of the East. Astrology served a definite and important purpose in the development of astronomy. By including this section we hope that the same service is rendered the exhibition: that people who might otherwise not be interested in astronomy will be intrigued by the more familiar astrological concepts and, having been intrigued, will visit the exhibition and learn. The attempt is not without some risk of misunderstanding, and the curatorial staff was somewhat reluctant to take the risk. It will be instructive, however, to see the public's response. Perhaps our stars will be lucky.

Aerial Navigation—Then and Now

Airplanes like this Fairchild PT–19 Cornell Trainer were once navigated entirely by flying over the terrain, moving from one clearly identified landmark to another. Perhaps the first example of this type of on-purpose flight from one point to another was Louis Bleriot's trip across the English Channel in July 1909.

Frank Kingston Smith

Frank Kingston Smith is a 10,000 hour pilot with instrument and multi-engine ratings. He has written ten books about aviation, as well as more than 450 magazine articles and is an editor-at-large for *AOPA Pilot*, the magazine of Aircraft Owners and Pilots Association. He is much in demand as a dinner speaker all over the U.S. and Canada and has appeared on many radio and television talk shows.

Navigation—the very term usually elicits the image of someone wielding a spyglass or sextant. Although thousands of airplanes shuttle between communities in the U.S. everyday, few nonflyers have any idea about how airplanes, from airline jets to small private aircraft, navigate from one place to another by simply turning on a radio, twisting a knob to tune into an appropriate frequency, and then rotating a couple of other knobs to determine the exact course to fly. Modern airborne equipment links up with ground-based stations and provides a visual indication of the airplane's position, ground speed, and progress throughout the flight. It was not always so.

Airplanes were once navigated entirely by picking one's way over the terrain and then proceeding from one clearly identified landmark to another. Perhaps the first example of on-purpose flight from one point to another was Louis Bleriot's flight across the English Channel in July 1909 in a monoplane of his own design. It took 36½ minutes for the 25 horsepower engine to carry him on that 38-km (23½-mi.) trip. Bleriot took off from Calais and kept his eyes riveted on the white cliffs of Dover, which loomed on the rim of the western horizon. That was short range visual navigation; Bleriot's airplane had no compass.

In 1911, only eight years after the Wright brothers' first flight at Kitty Hawk, Lincoln Beachey (then one of the Curtiss exhibition pilots) flew a rickety, box kite-like biplane from New York to Philadelphia, covering the 145 km (90 mi.) in 2 hours 22 minutes, to demonstrate that airplanes did have some transportation value. Because he sat out in the open, he could not use a chart—nor did he have a compass. His navigation aid was intercity railroad right-of-ways, which were soon to be known to all aviators as the "Iron Compass." Within months, the pilot of a Wright Model Ex made an even more dramatic flight: Calbraith P. Rodgers flew across the U.S. in a winding course, following railroad tracks all the way. His flight was followed by a supply and support train, so that it was necessary for the epic flight to follow abutting railway trackage.

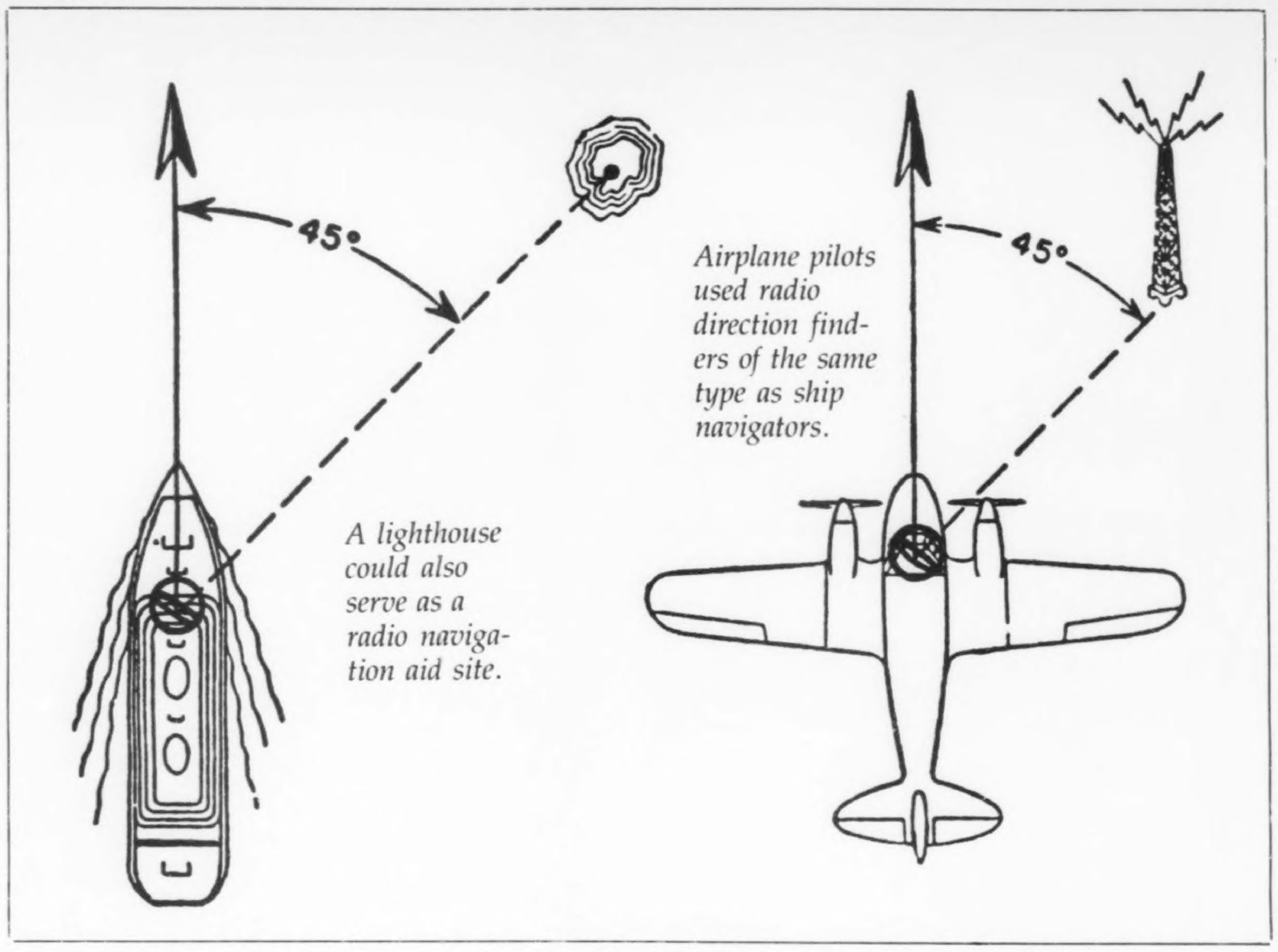
Such cross-country navigation is known as "pilotage." It is still possible to fly by pilotage when the weather is good, using modern air navigation (aeronautical) charts, with the pilot/navigator feeling his (or her) way, constantly comparing details on the chart with landmarks on the ground. Many lightplane, strictly recreational pilots still fly by pilotage, skimming along at altitudes below 914 m (3000 ft.) following rivers, power lines, railroads, and the "Concrete Compass"—the highly visible Interstate Highway System.

After World War I, pilots of open cockpit airplanes with magnetic compass installations began to use a new form of direct point-to-point cross-country navigation: "dead reckoning," a corruption of the word "deduced." Dead reckoning was first used by sailors operating out of the sight of land. The premise is that if one knows a ship's—or airplane's—position or point of departure, a line can be drawn on a chart to the destination and the distance measured. Knowing the speed of the ship and holding the compass course laid out on the chart, the navigator can predict how long it will take to transit the distance. Upon departure, the time is noted and the estimated time en route (ETE) added to generate an estimated time of arrival (ETA). When the latter comes up on the clock or chronometer, the navigator can deduce that the ship is in the vicinity of the destination and can begin to scan for landmarks (in shipping, a landfall) to complete the trip visually.

In practice, many affective factors must be computed into the basic theory. A crosscurrent will move the ship—or aircraft—off to the side of the baseline course; proceeding against a current will lengthen the time en route; going in the same direction as a current will shorten it. There are also intrinsic problems with every magnetic compass installation, called "deviation." The dislocation of the magnetic North Pole, which lies in Canada, from the geographical North Pole creates what is called "magnetic variation." On a ship moving at relatively slow speeds, dead reckoning is leisurely compared with a

161-km/hr (100-mph.)—or faster— airplane. But it is a valid form of aerial navigation: Charles A. Lindbergh dead reckoned his way for 33 hours from New York to Paris and a few months later for 27 hours from Washington, D.C., to Mexico City, most of both flights took place in bad weather at night. During World War II, navigators used dead reckoning to lead aircraft fleets for hundreds of kilometers across hostile territory, because all ground-based radio stations were shut down as a precaution against their use by the enemy.

Radio navigation was introduced in the late 1920s, primarily for the use of the then-new passenger carrying airlines flying 161-km/hr (100-mph.) Fokker, Stinson, and Ford Tri-Motor aircraft. Pilots of those early airliners flew in poor visual conditions, picking their way across the countryside by a combination of pilotage and dead reckoning, just as the barnstormers and early, open-cockpit airmail pilots had done. However, instrumentation for flying in clouds had been developed. Airline pilots could climb through an overcast, fly "on top" to their dead-reckoned destination, then descend through the undercast, hoping that when they broke out something would look familiar so they could complete the flight by old-fashioned pilotage. The thought of flying on airways in clouds without an air traffic control clearance makes modern pilots shudder at the in-flight collision hazard, but there were not many airplanes flying in those days.



A lighthouse could also serve as a radio navigation aid site.

Airplane pilots used radio direction finders of the same type as ship navigators.

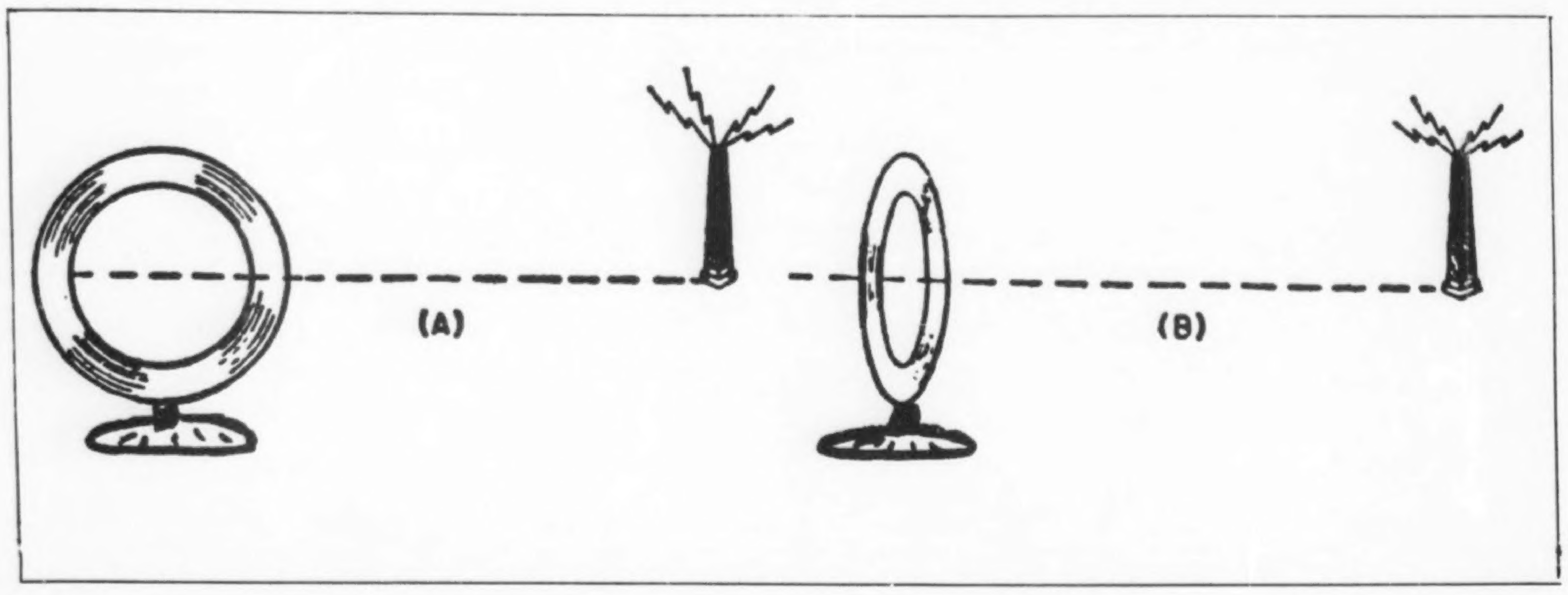
Radio navigation for both ships and aircraft inflight was the introduction of land or ground-based assistance when landmarks could not be seen because of weather conditions.

In the mid-1930s radio technology had advanced; all types of receivers had been reduced in size and complexity, and aircraft radio equipment had been created. It weighed 34 kg (75 lb.) and took the space of a couple of large suitcases, so that only large airplanes could carry it, but it immediately changed aviation navigation. The first giant step was the rotatable, direction-finding, loop antenna.

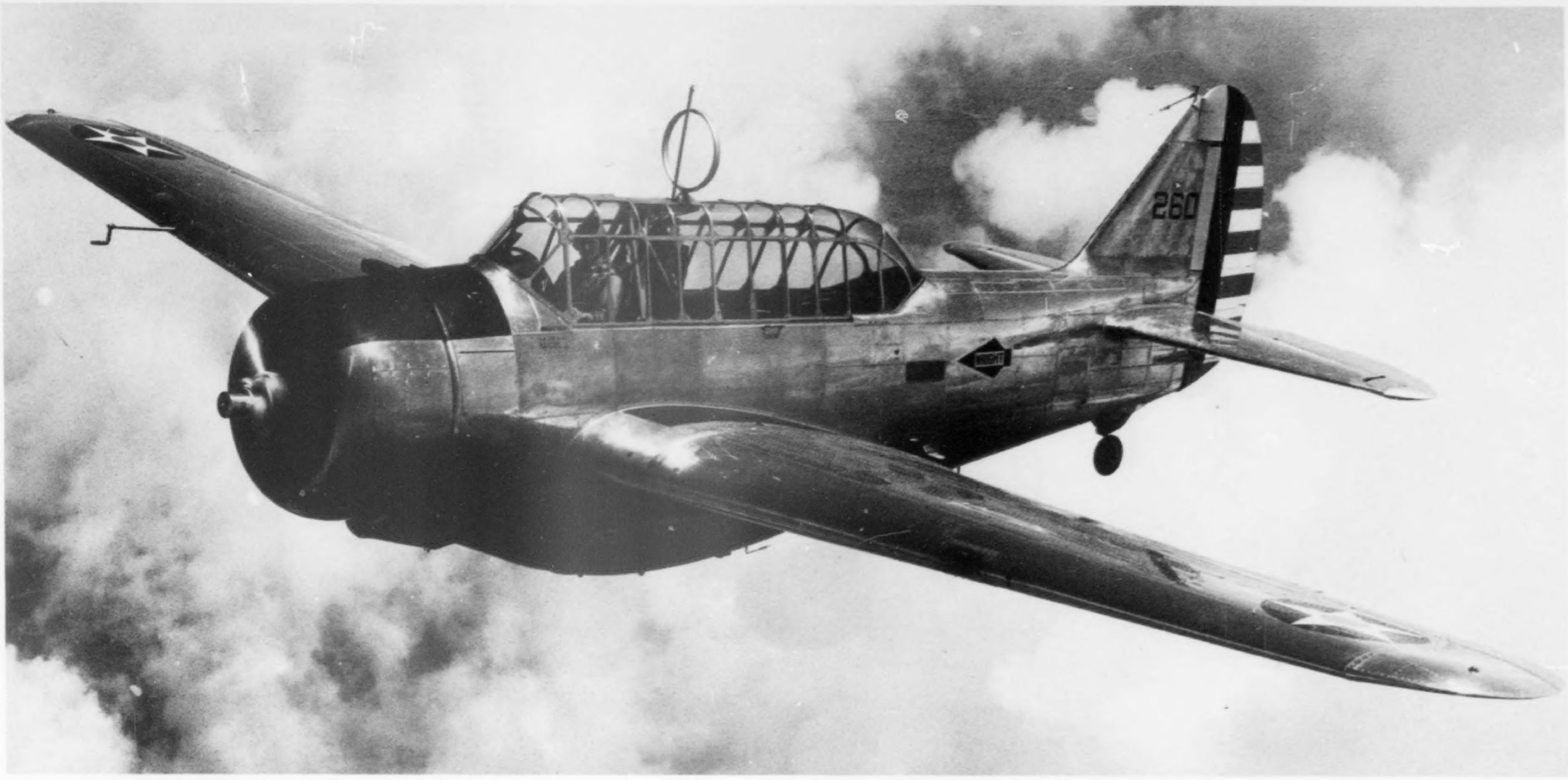
The radio direction finder (RDF) was another device adapted from ship navigation. By changing audible radio signal volume while rotating the loop antenna when the radio was tuned into a ground-based, low frequency station, a pilot/navigator could establish a line of position (LOP), or determine his bearings, from the transmitting station to the aircraft in flight. However, the RDF system had a serious ambiguity problem: the navigator did not immediately know whether he was tracking toward or away from the transmitter; it was possible to overfly a ground station and not know it without making many turns and course changes to obtain additional LOPs to be sure of the transmitter's location. Nevertheless, this crude and clumsy loop antenna was in airline and military use until the late 1940s, when it was supplanted by a new device: the automatic direction finder (ADF). An ADF dial, with a center-pivoted needle mounted on the instrument panel, provided immediate directional information. When the radio was tuned in to the nondirectional radio beacon (NDB) the needle would swing and point directly at the station. The ADF is still widely used today, not only to tune in to the FAA's NDB system, but also to use commercial, low frequency, broadcast stations so that in good weather pilots can listen to news or music while navigating.

However, during the late 1930s, as faster airplanes such as the Boeing 247D and the DC-3 came into use, the nondirectional ADF was not precise enough to define the new system of aerial highways known as civil airways. To provide the requisite accuracy, radio engineers created a new, low frequency, radio range system. The heart of the airways system was a horizontal antenna that emitted a signal in the shape of a figure "8" perpendicular to the antenna wire, or aerial. By siting two crossing antennas, the edges of the dual figure 8 signals could be overlapped. Then, if one antenna emitted the Morse Code letter "A" (dit-daah) and the other emitted the letter "N" (daah-dit), the area of overlap would transmit both signals, which merged into a steady hum that was heard over the pilot's headphones. This "aural" (heard) signal was called a "radio beam," and a pilot flying on-course was "on the beam." By locating a series of aural ranges along the airways with the beams pointing at each other, radio beams led airplanes over the charted routes shown on air navigation charts.

For the first time, it was possible for pilots to fly on schedule when the weather was too poor for visual flight, or pilotage. Not only were pilots able to climb and descend through clouds, but they were able to fly through them con-



The rotatable RDF loop antenna produced the strongest signal when the loop was parallel (A) to the radio signal and at its weakest when set at right angles (B) to the transmitter. For navigational use, the weakest aural signal was the most accurate for determining a line of position.



In the mid-1930s, the first giant step in the development of the advancing radio technology was the rotatable, direction-finding, loop antenna. This late 1930s North American 0–47 observation plane makes use of the RDF (radio direction finder). This crude and clumsy loop antenna was in airline and military use until the late 1940s, when it was supplanted by the automatic direction finder (ADF).

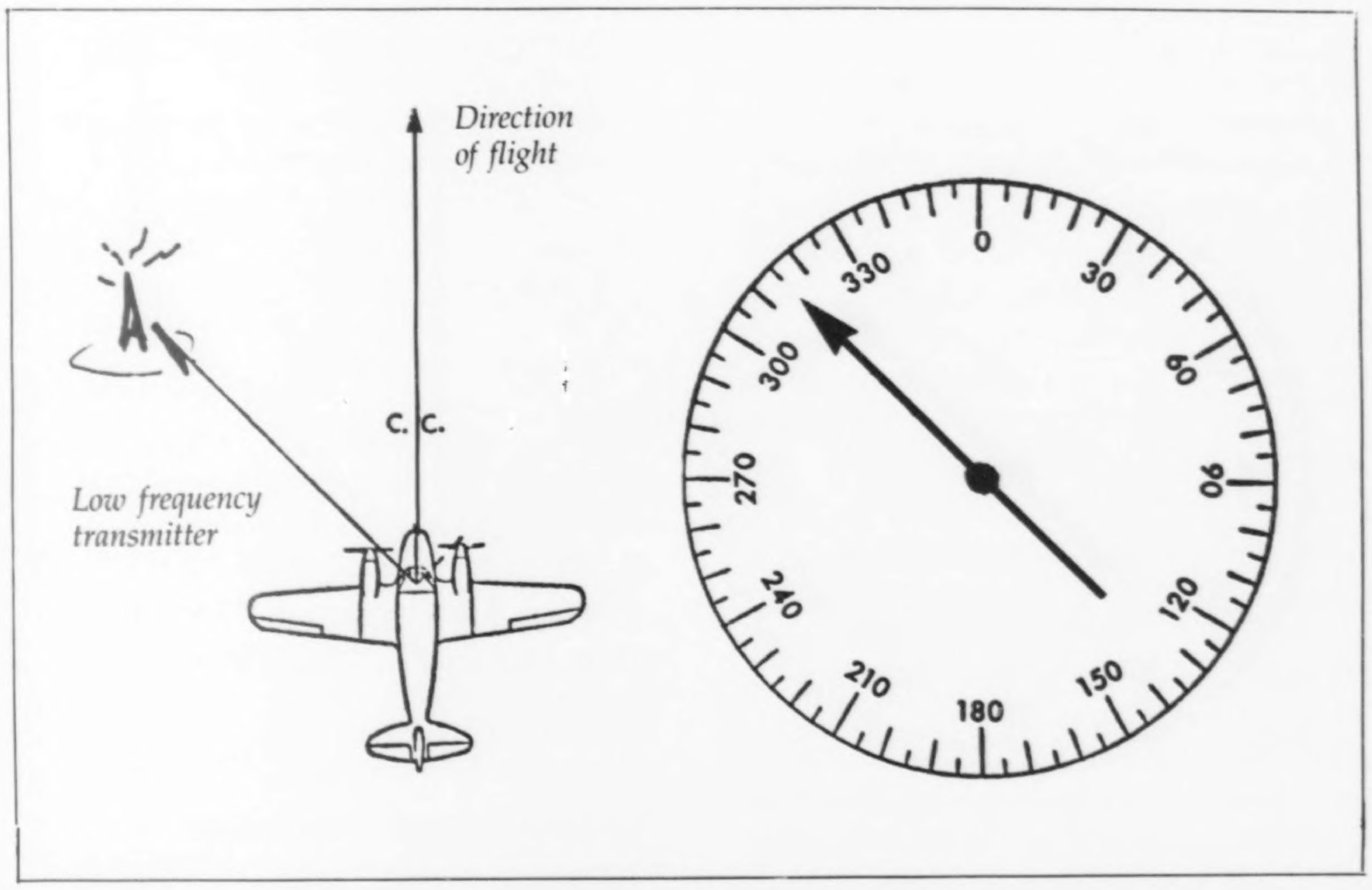
tinuously, staying on airways by riding the invisible beam. Furthermore, they were able to use the ground-based radio to make instrument approaches to land by following certain procedures and by making timed turns (procedure turns) until they could descend low enough to see the ground and make the landing visually.

However, in actual operations, low frequency amplitude modulation (AM) radios had a serious shortcoming: meteorological interference—static. Aeronautical navigation and communication transmissions, like radio programs on commercial low frequency AM stations heard on home and automobile radios, were disrupted by thunderstorm activity, which created crashing static and made the ADF needle whirl wildly as it pointed at every lightning strike within range. When pilots most needed radio navigation aids (navaids) to make instrument flight—especially approaches to landings—thunderstorms either masked or completely obliterated their radio signals. Eventually, that problem, too, was solved by electronic wizardry.

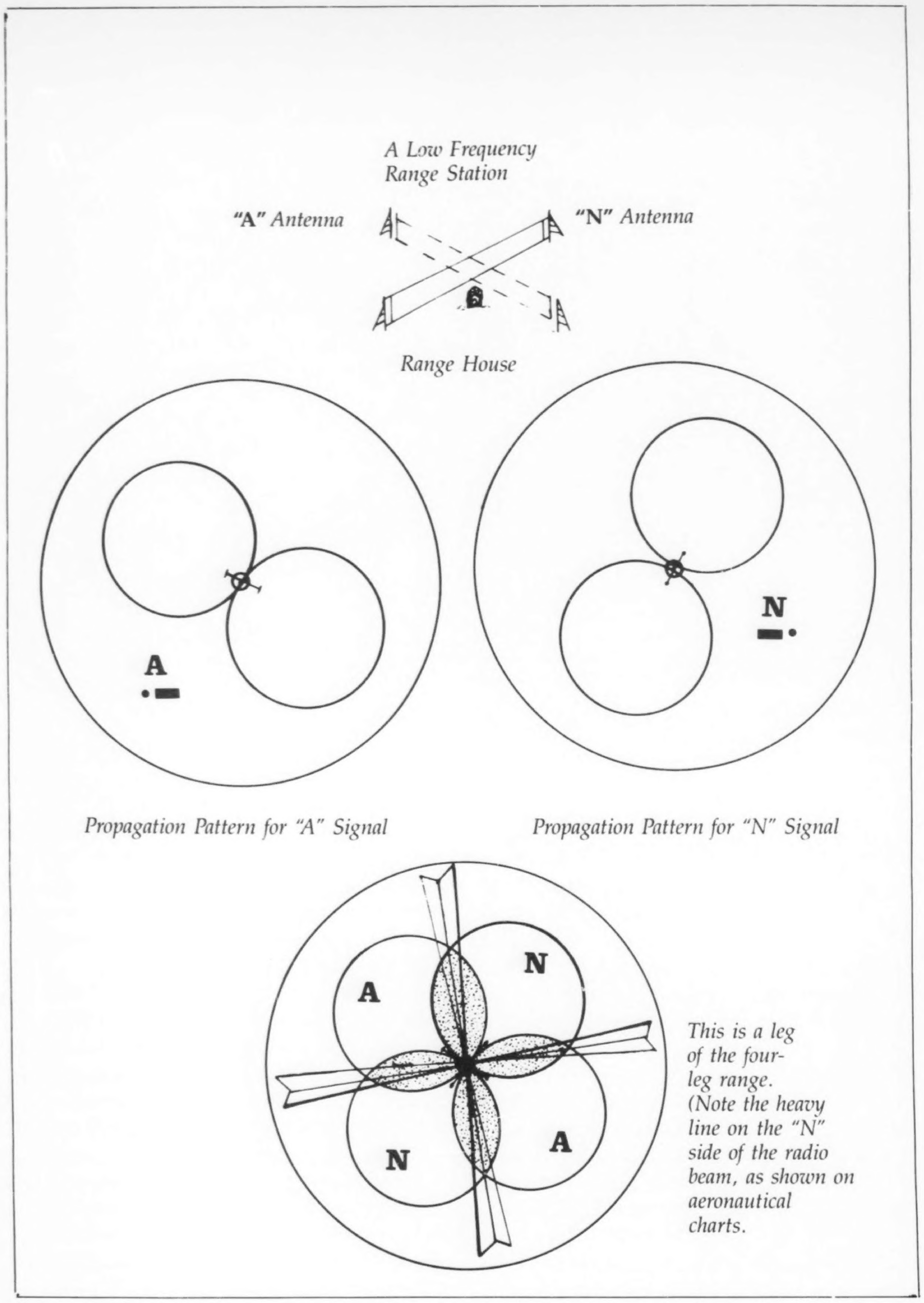
Early in World War II, a top secret discovery was how to use previously unavailable parts of the radio spectrum in the very high frequency (VHF) and ultra high frequency (UHF) bands. With that, electronics experts discovered the unique property of both VHF and UHF: radio reception was not affected by thunderstorm activity. A pilot could communicate without static interference, even when surrounded by lightning strikes. Furthermore, frequencies could be selected by the use of crystals in both transmitter and receiving sets. The only shortcoming was that, unlike the long-range, ground hugging ("ground wave propagation") signals of low frequency ground stations, VHF/UHF radio signals, traveled in direct "line-of-sight" from the ground station to the aircraft. At 152 m (500 ft.) VHF/UHF range was only 48 km (30 mi.), but it increased with altitude: an aircraft at 4572 m (15,000 ft.) could receive a signal from 253 km (157 mi.) away.

Another World War II top secret was that VHF/UHF radio signals were soon used for special navigation services. Army pilots who operated from and returned to fixed air bases could dead reckon both outbound and homebound courses, but naval aviators had a more difficult problem. They launched from aircraft carriers that could move 60 or 70 nautical miles in any direction from the launching point. Low on fuel and physically tired, pilots had a serious operational problem finding their carriers after a three- or four-hour sortie.

Electronics specialists developed a device that was mounted on carriers to radiate 360 separate VHF/UHF radio beams, one for each degree of the magnetic compass and always aligned with magnetic north. When within line-of-



Aircraft in flight use the low frequency ADF for orientation and en route navigation. It is useable with both FAA radio beacons and with commercial AM broadcast stations. The ADF display on the instrument panel of the aircraft at the left would indicate the direction of the radio station by a needle, without rotating a loop antenna.



Propagation Pattern for "A" Signal

Propagation Pattern for "N" Signal

This is a leg of the four-leg range. (Note the heavy line on the "N" side of the radio beam, as shown on aeronautical charts.)

When the simultaneous signals from the "A" and "N" antennas overlap, as in the shaded areas shown here, the pilot hears a steady hum from the overlapping morse code signals.

Definitions

ADF—automatic direction finder

RDF—radio direction finder

LOP—line of position

NDB—non-directional radio beacon

AM—low frequency amplitude modulation radios

aural—of or relating to the sense of hearing

navaids—navigation aids

VORs—VHF Omnidirectional radios Radio Ranges or Omniranges or Omnis

ILS—Instrument Landing System

Parts of the radio spectrum:

VHF—very high frequency bands

UHF—ultra high frequency bands

sight range, airborne equipment (detectors) in returning aircraft could select and isolate any one of those 360 radiated beams, called "radials," and indicate on the instrument panel (a) the magnetic course toward the ship, (b) whether the airplane was flying toward or away from the ship along that radial (thus eliminating the directional ambiguity of the old RDF rotating loop antenna system) and (c) the distance to the carrier deck in nautical miles.

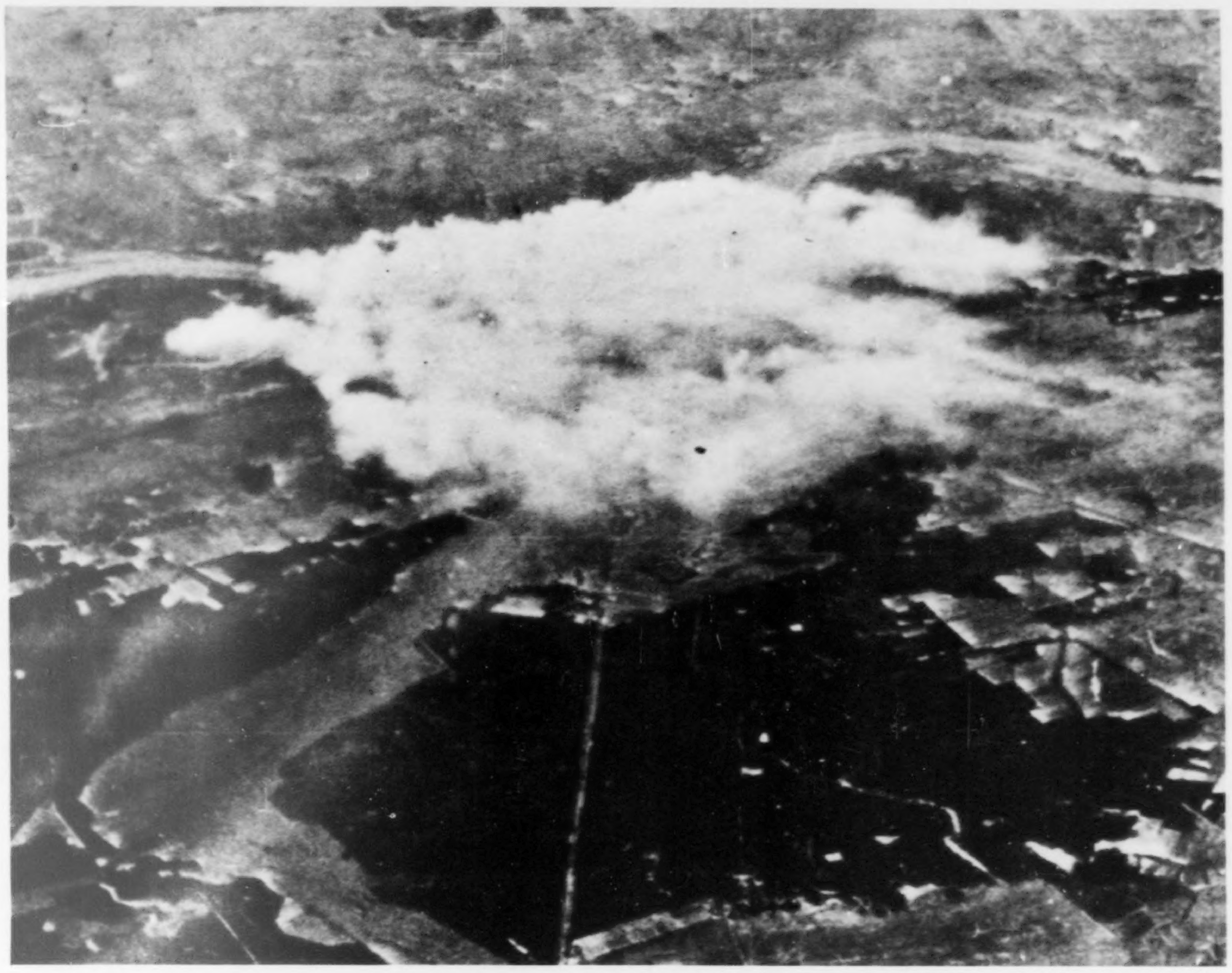
When the war ended, this equipment became the cornerstone of the modern airways system. The military retained the UHF part of the radio spectrum and the VHF segment was allocated to civil aviation. Within a few years the old, four-leg, low frequency, aural radio range airways structure was replaced almost entirely by the new technology that had been spawned by war.

Because the new ground-based stations on which the system was constructed operated in the VHF spectrum and were omnidirectional (in that they covered 360 degrees, rather than having only four legs) they were called "VHF Omnidirectional Radio Ranges," abbreviated as "VORs," but many pilots referred to them simply as "Omniranges," or "Omnis." The lines connecting the stations—the new civil airways—were called "Victor" (the phonetic alphabet letter for "V") and numbered on the charts as V-1, etc. Today, hundreds of Victor Airways crisscross the U.S., an invisible latticework of electronic guidance available to all aviators.

Now, precise cross-country navigation is possible for all pilots, professional and private. Modern aviation electronics (avionics) are so miniaturized that dual installations of navigation and communications (nav/com) radios are commonplace in small private airplanes. Weighing only a pound or two and taking up no more space than a couple of cartons of cigarettes, they have 720 crystal-controlled communication frequencies and 200 navigation frequencies. Many small airplanes, and virtually all of the large ones, are equipped with autopilots with "couplers" that hook onto a VOR radial and fly precisely along its centerline, automatically compensating for crosswinds by setting up a crab angle. They can also make instrument approaches to special VHF Instrument Landing System (ILS) equipped airports.

The VOR system of navigation made transportation in small private airplanes a practical reality, and it is the reason for the enormous growth in personal flying for business and pleasure. As technology moves ahead in giant strides, new and better air navigation systems will evolve, but flying and navigating in the airspace over the U.S. will be carried on utilizing the VOR system for years to come. ■

Smoke Job



Bridge, bridge, where is the bridge? This is an excellent example of screening a pinpoint target. The intent of the German's massive smoke screening effort was to deny allied bombardiers an accurate aiming point. Bombardiers had to be able to see the target clearly for several minutes before reaching the bomb release point.

Dino A. Brugioni

Dino A. Brugioni recently retired from the Central Intelligence Agency, where he worked as a senior official in aerial reconnaissance and photo interpretation. He has a great interest in the use of aerial photographs for historical documentation. During World War II, he flew 66 bombardment and many reconnaissance missions over North Africa, Italy, Yugoslavia, France, and Germany, where he witnessed the smoke screens described in his article.

The use of smoke to conceal military operations is a technique almost as old as warfare itself. Smoke has always been considered an essential tool to screen offensive movements or to hide retreats or disengagements on both land and sea. In World War II, however, a new dimension to smoke was added by the Germans—the strategic, defensive deployment of smoke generators to protect essential war industries and key transportation targets from Allied aerial bombardment. The Germans knew that Allied bombers would not bomb through an overcast; therefore, on clear days they sought ways to create smoke screens of sufficient size and density to protect their targets.

After much experimentation, the Germans developed a standard smoke generator that used chlorosulfonic acid ($ClSO_3H$) as the smoke generating agent. Grayish-white in color and harmful if breathed, the smoke discolored surrounding vegetation and left a white residue. As part of carefully planned defenses, the generators were spaced at intervals varying from 46 to 137 m (150 to 450 ft.) and were deployed along roads, paths, riverbanks, crests of hills, in open fields, and on self-propelled barges in the principal ports and naval bases. While most of the land-based generators were permanently emplaced, mobile generators were used to fill gaps in the smoke screening scheme. Maintenance and operational crews were assigned to blocks of 10 to 12 generators.

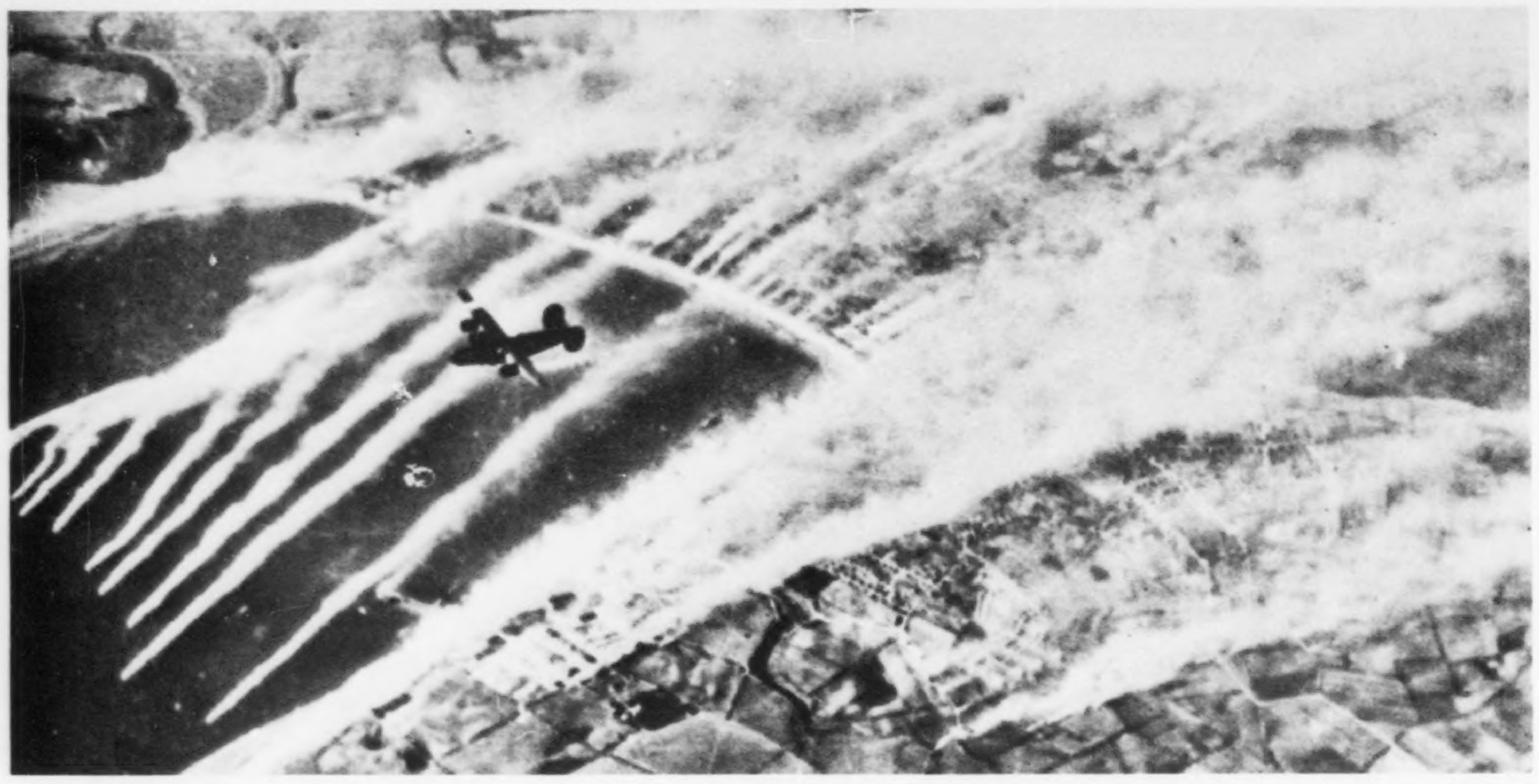
Weather conditions determined the effectiveness of smoke screens. The Germans had calculated that ideal weather conditions would be an 8-km/hr (5-mph.) wind velocity and 60 to 70 percent humidity. The generators were spaced so that the smoke plumes from each would form into a single mass about 274 m (900 ft.) from the generators. The density of the smoke varied from about 37 to 110 m (120 to 360 ft.). More generators were usually deployed on the prevailing wind side of the target. An elaborate warning system enabled the Germans to lay an effective screen within 10 to 15 minutes of warning. The smoke generators were operated in all weather conditions and against both day and night Allied bombing operations.

The World War II bombardier's maxim was, "If you can't see it, you can't hit it." The intent of the German's massive smoke screening effort was to deny Allied bombardiers an accurate aiming point. In making the bomb run required by the mission, the bombardier had to be able to see the target clearly for several minutes before reaching the bomb release point. If defensive smoke was deployed, it meant that the bombardier had to sight the target diagonally through a smoke mass that placed even more smoke between the bomber and the target at a very critical point. If the target was completely obscured by smoke, the mission commander had to make a choice: "bomb the screen," i.e., estimate the location of the target; make a second bombing run and hope for the best; or go on to an alternate target.

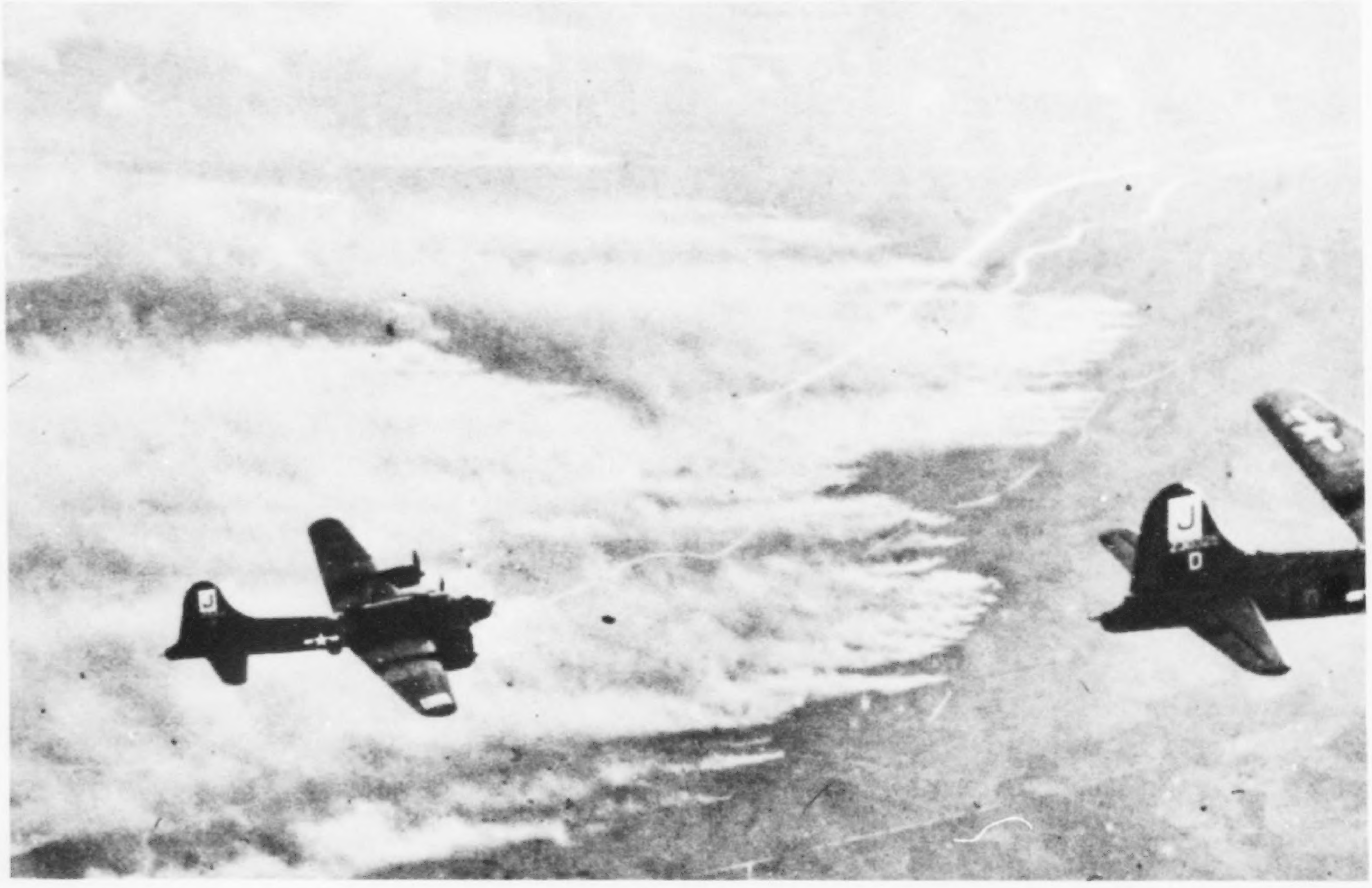
If the commander decided to "bomb the screen," he knew that fewer of the bombs would strike the intended target. In the case of bombing small or concentrated targets such as dams and bridges, there could be complete misses. When several commanders chose to "bomb the screen," the Germans reacted by increasing the smoke screen to roughly 10 times the size of the target area. They also employed decoy smoke screens, often causing bombardiers to drop bombs miles away from the intended target.

The bombardiers needed to resolve their dilemma, and photo interpreters responded by being able to precisely pinpoint the location of active smoke generators.

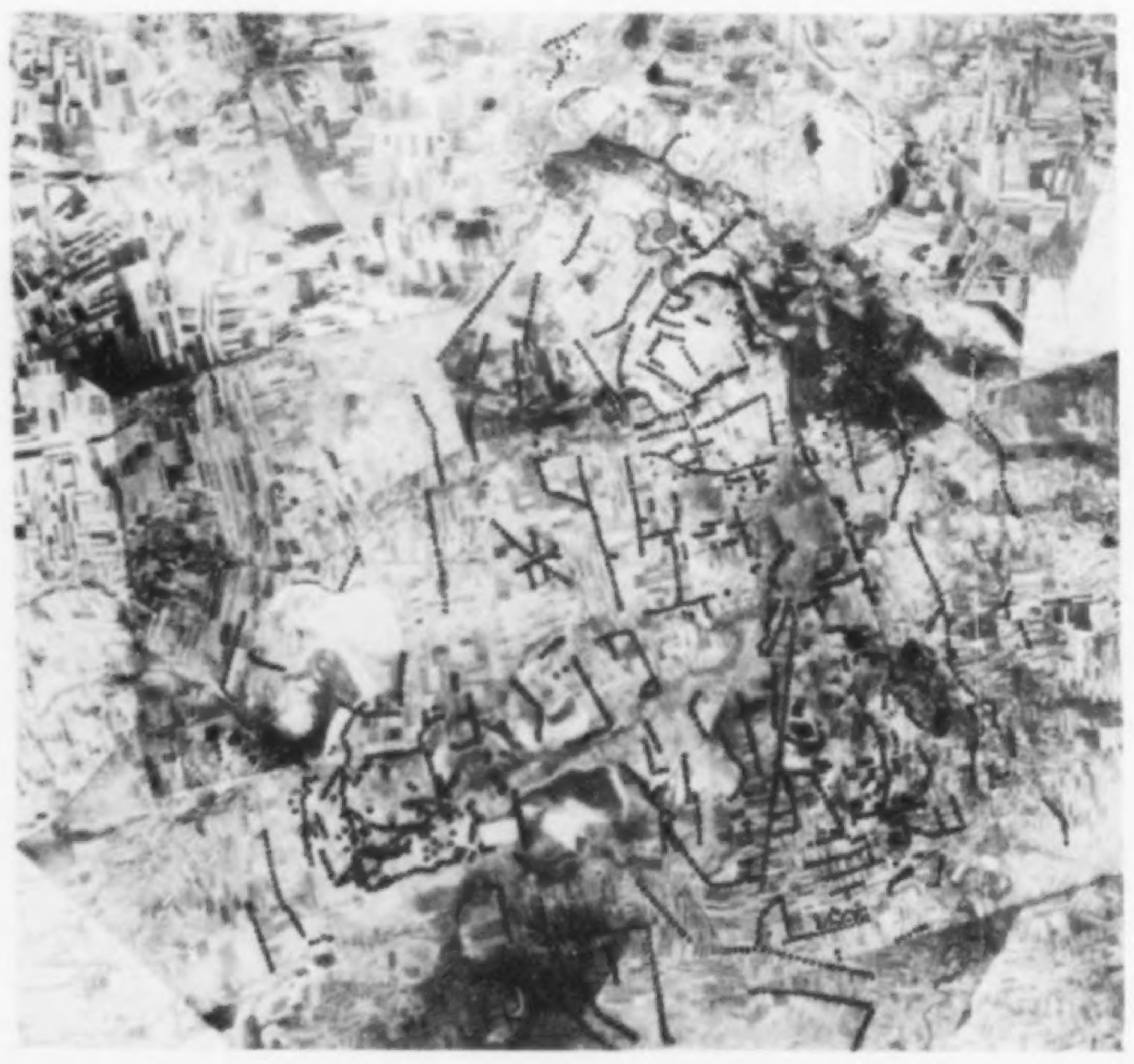
The interpreters could also spot discolored vegetation, the generator's smoke residue, the servicing trails that led to the generators, and even the generators themselves. They were asked to plot all the generators they could find within a given target area. Using photo mosaics, maps, and charts, the positions of the lines of generators were



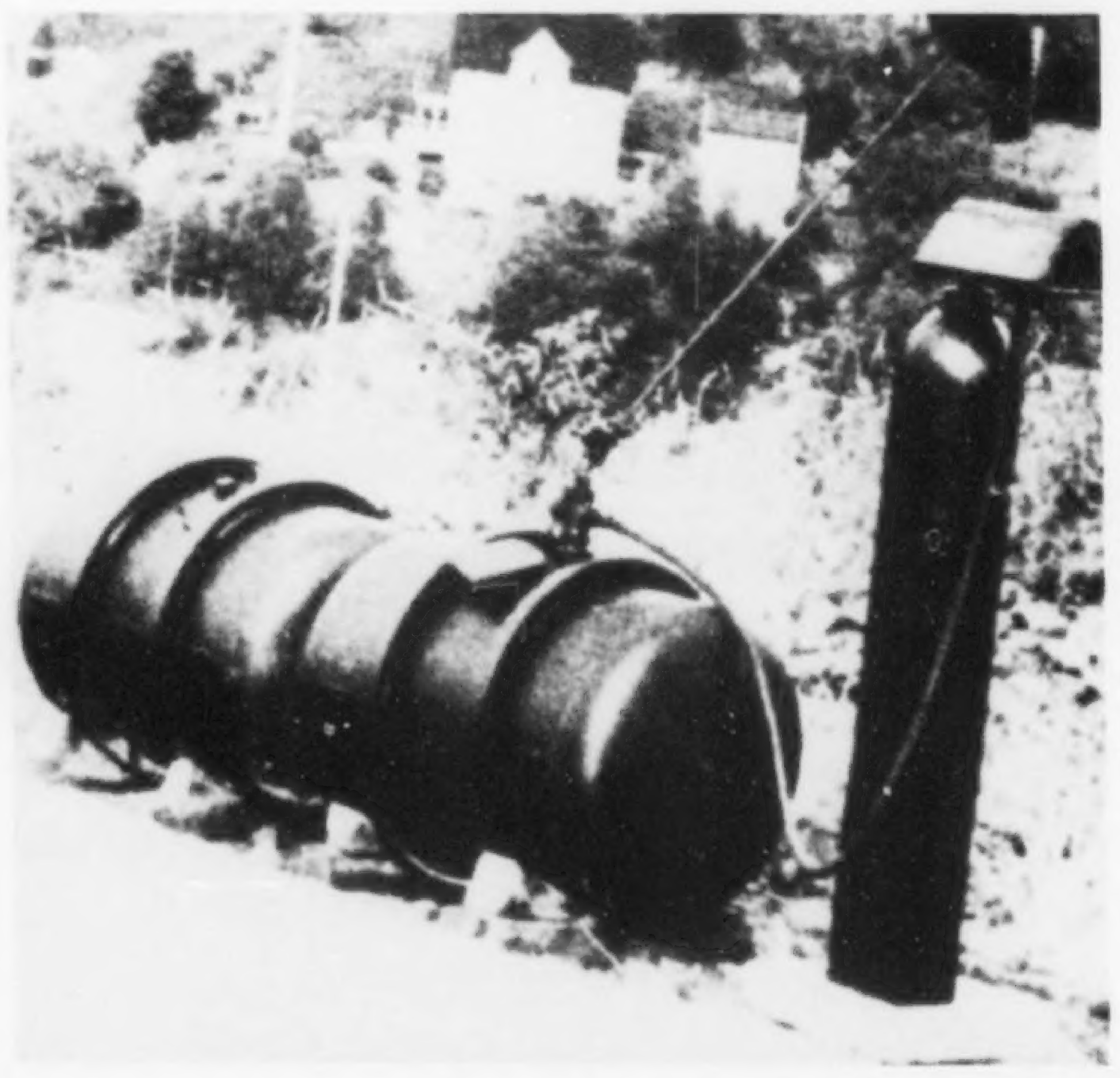
These smoke barges were correctly positioned, but a strong on-shore wind caused them to produce an ineffective screen at Eckernforde, Germany. Although they were operated in all weather conditions, the Germans had calculated that ideal weather would be an 8-km/hr (5-mph.) wind velocity and 60 to 70 percent humidity. The generators were spaced so that the smoke plumes from each would form into a single mass.



The World War II bombadier's maxim was, "If you can't see it, you can't hit it." The intent of the German's massive smoke screening effort was to deny Allied bombardiers an accurate aiming point. This very effective smoke screen forced these B–17s of the 390th bombardment group of the 8th Air Force to go on to an alternate route.



This smoke screen plot of the Merseburg, Germany, area shows each individual smoke generator. More generators were usually deployed on the prevailing wind side of targets. An elaborate warning system enabled the Germans to lay an effective screen within 10 to 15 minutes of warning.



The Germans developed these standard smoke generators that used chlorosulfonic acid ($C1SO_3H$) as the smoke generating agent. The grayish-white smoke discolored vegetation, left a white residue, and was harmful if breathed.

plotted on "smoke screen plots." Using these plots, the bombardiers selected checkpoints outside the screen, determined the precise distance of the target under the screen from a known point, and aligned the bombsight for an offset bombing run on what would be an invisible target.

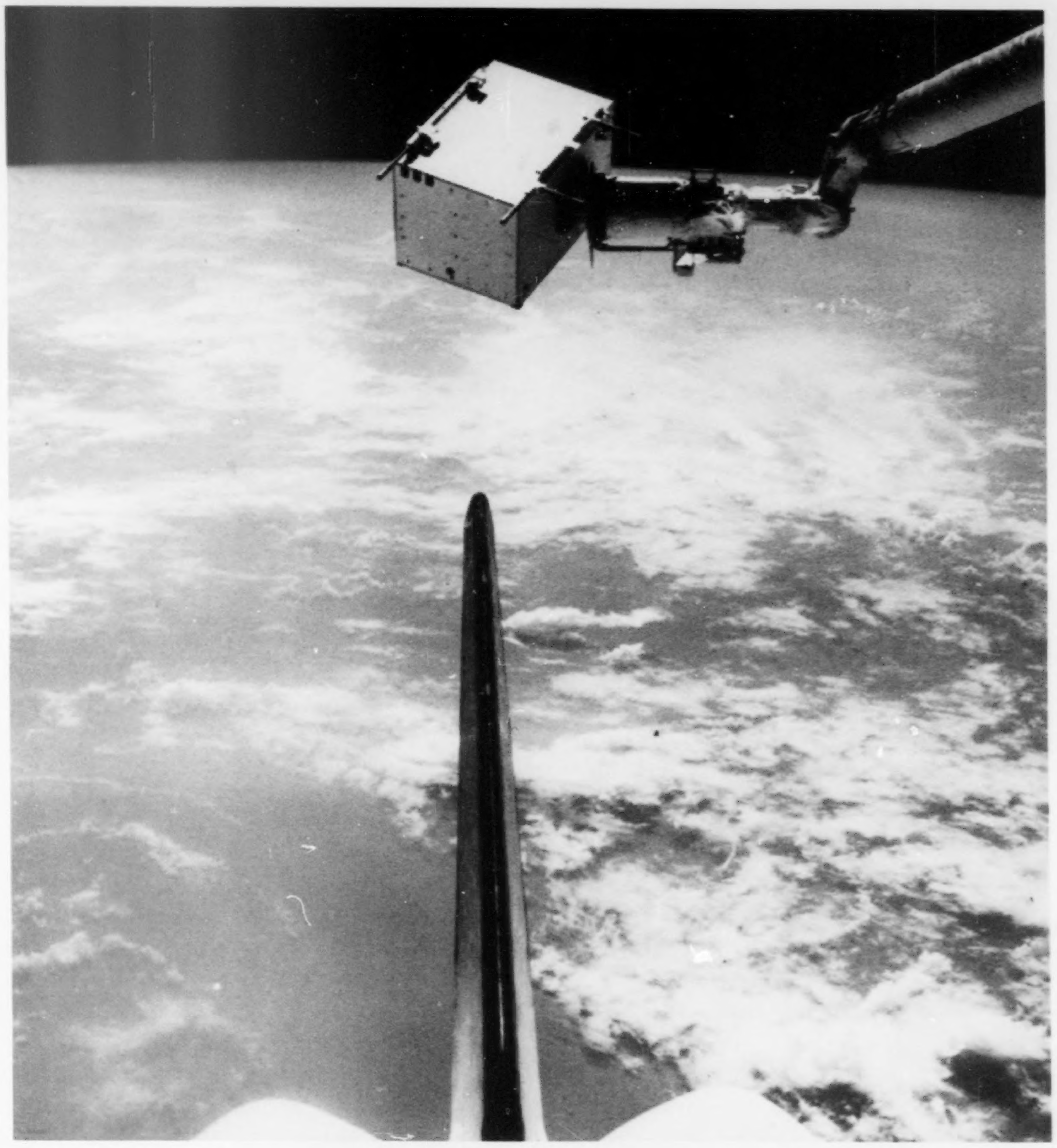
By war's end, thousands of generators were in use. In the Merseburg area alone, there were over 2100 generators capable of screening an area 19 by 23 km (12 by 14 mi.). This was the largest smoke screen capability observed in Germany. The smoke screening capability of the Bremen-Vegesack area of Northern Germany was also immense, often extending for 29 km (18 mi.) along the Weser River and in some areas 11 to 16 km (7 to 10 mi.) in width. Varied industrial and transportation targets were shielded by these massive screens.

In late 1944 and early 1945, the Allies concentrated a massive bombing effort on German synthetic fuel and chemical plants. Although most of the chemical plants were protected by smoke screens, the bombing took its toll on them and on the production of the chemical required to generate the smoke screens.

The demand for smoke chemicals had become enormous. Each air raid alert, whether for passing bombers or for a single reconnaissance plane, resulted in at least 15 minutes of operation of the generators. In a single 8th Air Force bombing raid on the Merseburg area, which lasted for about an hour, over 100,000 liters (26,417 gal.) of smoke chemicals were consumed. The problems of maintaining an adequate supply of smoke chemicals became critical and may explain why the generators were no longer operating at certain targets by 1945. This, however, did not hamper German experimentation for improving their chemical defenses. During a bombing attack on the Bitterfeld Complex near the end of the war, an effective smoke screen was operational in a matter of seconds rather than minutes. Meanwhile, the Allied air forces were also actively experimenting with ways to defeat the smoke screens, utilizing sophisticated instrumentation and radar bombing techniques.

The many World War II aviators who watched the plumes rise from separate generators and gradually form into a single massive smoke screen experienced the frustration of having the target obscured but also watched these man-made spectacles with a certain fascination. Today modern radar bombing equipment and techniques permit the penetration of clouds and smoke. Those of us who flew in World War II observed smoke jobs the like of which will probably never be seen again. ■

Space Flight—
A
New
Perspective



This view from the Space Shuttle of the North Atlantic Ocean southeast of the Bahamas serves as a backdrop for this 70mm scene of the Columbia's remote manipulator system (RMS) arm. The hand-like device, or end effector, is grasping a multi-instrument monitor for detecting contaminants. The Columbia's vertical tail and orbital maneuvering system (OMS) pods are in the foreground.

Gregory P. Kennedy
Department of Space Science and Exploration, NASM

During the first two decades of manned space flight (1961-81), the main emphasis was on *exploration*. But, the vantage point and environment of space offers many possibilities for terrestrial applications. During the second of the two decades since Yuri Gagarin first orbited the Earth aboard *Vostok-1* on April 12, 1961, we've seen a shift away from manned space exploration to space *exploitation*. There have been hinderences to such exploitation, however, one of them being the high cost of reaching space using expendable launch vehicles. In the early 1970s, NASA planners sought to develop a reusable space vehicle that would reduce these high costs. This reusable vehicle is today's Space Shuttle.

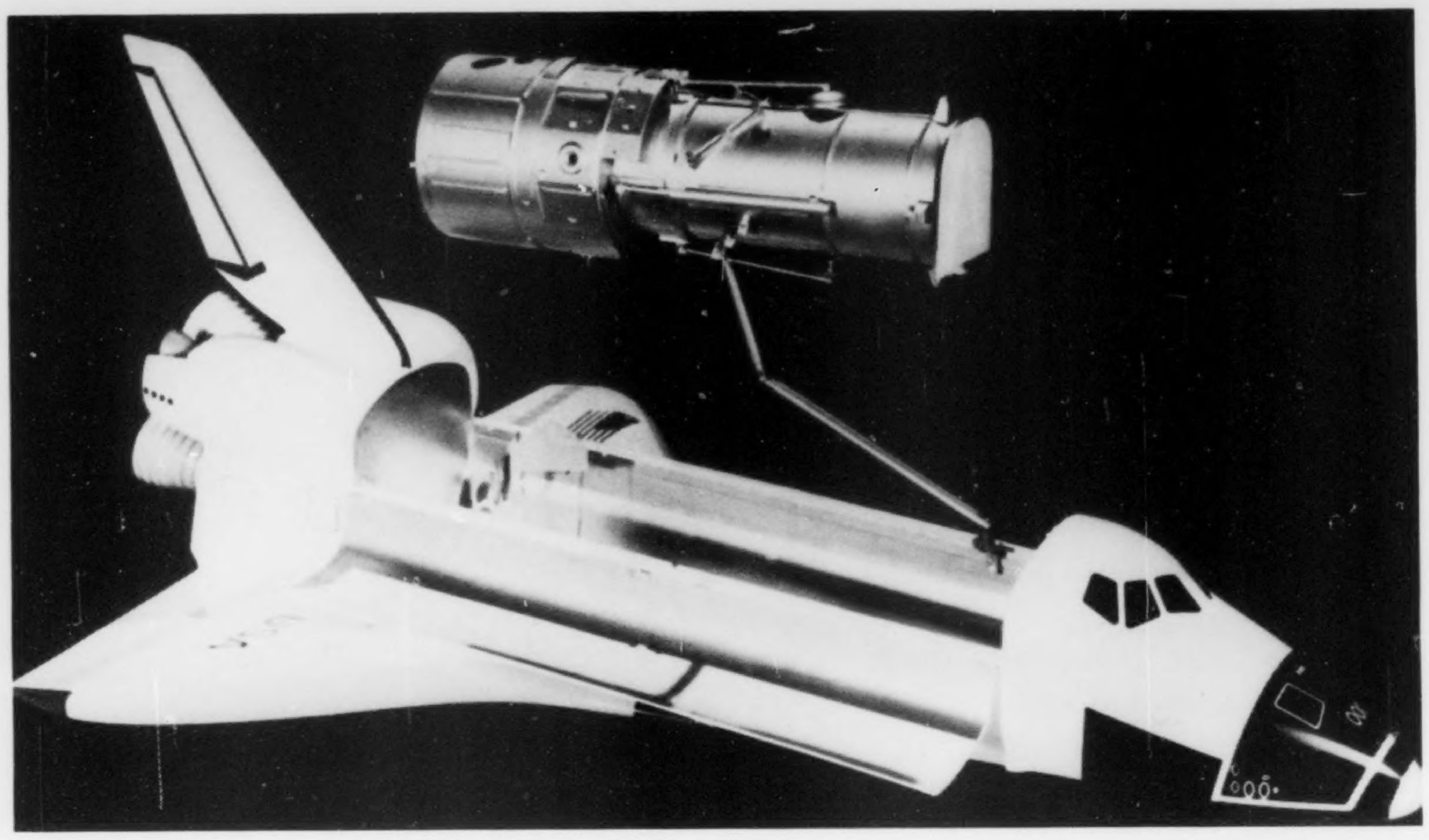
With each flight, our knowledge of the Space Shuttle and its capabilities is expanding. The 15-m (50-ft.) articulated manipulator arm, which was added for the second flight, will be used extensively on future flights to move satellites in and out of the cargo bay. Controlled from within the Orbiter, this arm has three joints, the shoulder, elbow, and wrist, and a "hand" called an end effector that can "grasp" a specially designed grapple. It will be placed on many future satellites.

Columbia's fourth and final test flight began on June 27, 1982. This mission featured further arm tests and the first Shuttle payload for the Department of Defense. Military involvement in space is not new—the armed services have been using satellites for communications, navigation, and reconnaissance for over 20 years. What is new is having such payloads aboard a U.S. manned spacecraft. Nearly one-third of all future Shuttle launches will carry non-weapon payloads for the Defense Department. Thomas Mattingly and Henry Hartsfield landed *Columbia* at the Dryden Research Center on the fourth of July. On hand was the second Orbiter qualified for space flight, the *Challenger*.

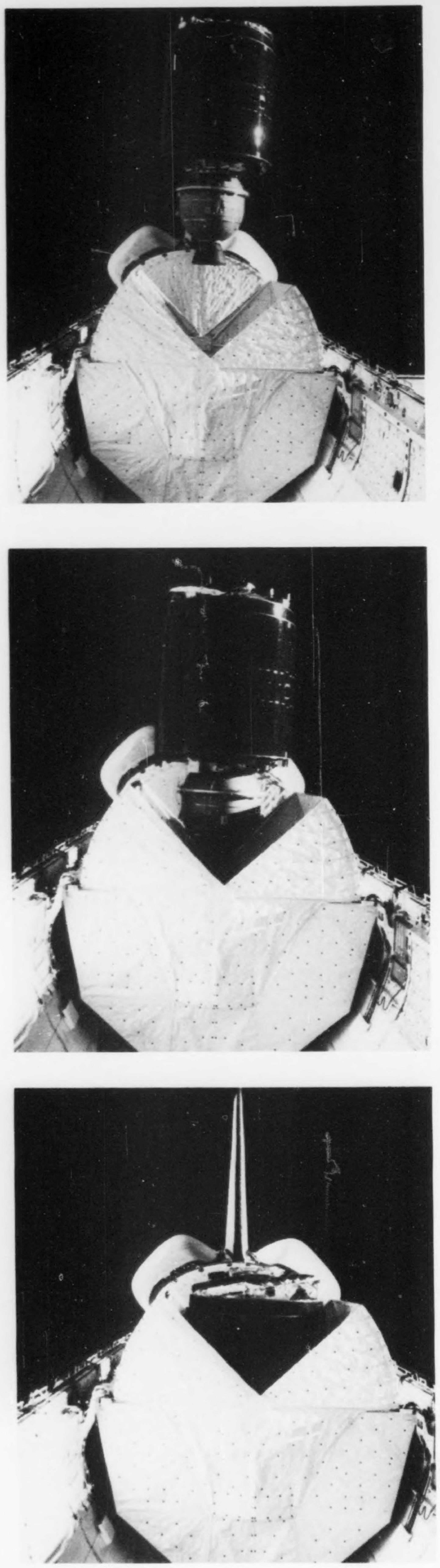
Eventually, there will be at least four Orbiters, *Columbia*, *Challenger*, *Discovery*, and *Atlantis*. Each will be capable of 100 flights, and together they will form a fleet that will be the backbone of the Space Transportation System. In addition to the Orbiters, the Space Transportation System includes the ground support facilities for Space Shuttle operations.

Space Shuttle Orbiters are limited to altitudes of less than 1100 km (700 mi.), and many of the commercial satellites planned for future missions orbit at an altitude of 36,000 km (22,300 mi.). A satellite orbiting at this altitude takes 24 hours to complete one orbit, so if placed over the equator, it will appear to remain motionless in the sky. Solid propellant rocket motors attached to the satellites bridge the gap between the Shuttle's capabilities and the desired higher-altitude orbits. In use, the satellite with such an upper stage motor attached is launched from the Orbiter. Once the Shuttle reaches orbit, the crew releases the satellite/motor combination from the cargo bay so the upper stage can boost the satellite to geostationary altitude. NASA currently has three different upper stages for Shuttle payloads available as parts of the Space Transportation System.

One of these stages, the Payload Assist Module-D (PAM-D) propelled the communications satellites carried on the Shuttle's first operational flight in November 1982. Two satellites rode in the cargo bay during this mission, which was the fifth flight for the Orbiter



The Space Telescope is a multi-purpose optical telescope planned for launch into orbit by the Space Shuttle. It will be the most powerful telescope ever built, enabling scientists to gaze seven times farther into space than ever before. Astronomers will look at celestial sources such as quasars, galaxies, gaseous nebulae, and Cepheid variable stars that are 50 times fainter than those seen by the most powerful telescopes on the ground.



The Satellite Business System (SBS-3) spacecraft spins and then springs from its protective "cradle" in the cargo bay of the Earth-orbiting Space Shuttle Columbia *and heads toward a series of maneuvers that will eventually place it in a geosynchronous orbit. This moment marked a milestone for the* Space Transportation System *(STS) program, as the placement of the communications satellite represented the first deployment of a commercial satellite from an orbiting space vehicle. Part of* Columbia's *wings can be seen on both the port and starboard sides.*

Columbia. Soon after launch on November 11, 1982, astronauts Vance Brand, Robert Overmeyer, Joseph Allen, and William Lenoir watched as the Satellite Business Systems (SBS) spacecraft rose out of *Columbia's* cargo bay. Springs ejected the satellite from the bay, with its upper stage attached. The next day, the astronauts deployed the Canadian Anik C-3 satellite in the same manner. SBS and Anik were the first commercial payloads carried by the Shuttle. In the near future, there will be many such spacecraft carried aboard the Space Transportation System. One of the biggest advantages to launching satellites with the Shuttle is that the crew can check them before release to make sure they're operating properly. If a satellite malfunctions before release, the astronauts can bring it back to Earth for repair. With unmanned expendable launch vehicles, if a satellite has a problem, it's usually lost.

Another advantage to using the Shuttle is that it can carry more than one satellite at a time. Although the total cost of launching a Shuttle may exceed the cost of an expendable launch vehicle, if more than one satellite is carried in the cargo bay, the organizations that supply the payloads share the cost, like a space-bound "carpool." This way, the cost per satellite drops dramatically, making the Shuttle cheaper to use. Payload pricing methods vary and are dependent upon the payload's length and weight. This way, users pay a fair proportion of the launch costs.

When the *STS-5* flight ended on November 16, 1982, *Columbia* was temporarily retired for modifications. *Challenger* is planned for the next flight, *STS-6*. *Columbia's* next payload will be Spacelab-1, which flies aboard *STS-9* in the fall of 1983. Spacelab is a flying laboratory that remains in the cargo bay throughout the flight. A tunnel connects the cylindrical crew module to the Orbiter's crew compartment so personnel can climb into it and work as in a laboratory on the ground. Spacelab is built by a consortium of European nations for use on the Shuttle. It's first flight will also feature the first flight of non-NASA astronaut "payload specialists" aboard the Shuttle. Payload specialists are not career astronauts but are scientists, engineers, physicians, or technicians who will be allowed to do research in space. Anyone in good health can fly aboard the Shuttle, which in its operational configuration, can carry up to seven people. With a basic mission crew of three, the commander, the pilot, and the mission specialist, there's still room for four payload specialists.

Many different payloads are planned for future flights. In addition to the commercial payloads, the Space Shuttle will carry scientific satellites as well. One of the most fascinating, and perhaps most significant, is the Space Telescope. The Space Telescope is an orbiting observatory that will allow astronomers to see seven times farther and detect objects 1/50th as bright as they can with ground-based instruments. Scheduled for launch in 1985, this 2.4-m (94-in.) reflecting telescope will have a life of about 15 years. Space Telescope is unmanned; its images will be telemetered to astronomers on Earth. Astronauts will be able to repair the telescope or replace its instruments in space. In fact, if need be, it can be retrieved and returned to Earth for over-

This view of clouds over the Pacific Ocean was recorded by a 70mm handheld camera from the Space Shuttle Columbia *during STS–1. The camera was aimed through the aft window of the flight deck, looking toward the vertical stabilizer and the orbital maneuvering system (OMS) pods, which are silhouetted in the frame.*

Morocco's Atlantic Coast and some inland areas including what was formerly Spanish Sahara form the backdrop for this view of Columbia's *aft section during STS–3. The vertical tail of the reusable spacecraft almost splits the frame. Features on the Moroccan land mass include Rasel Malok, Wadi Saguia, and Hemada del Gadda.*

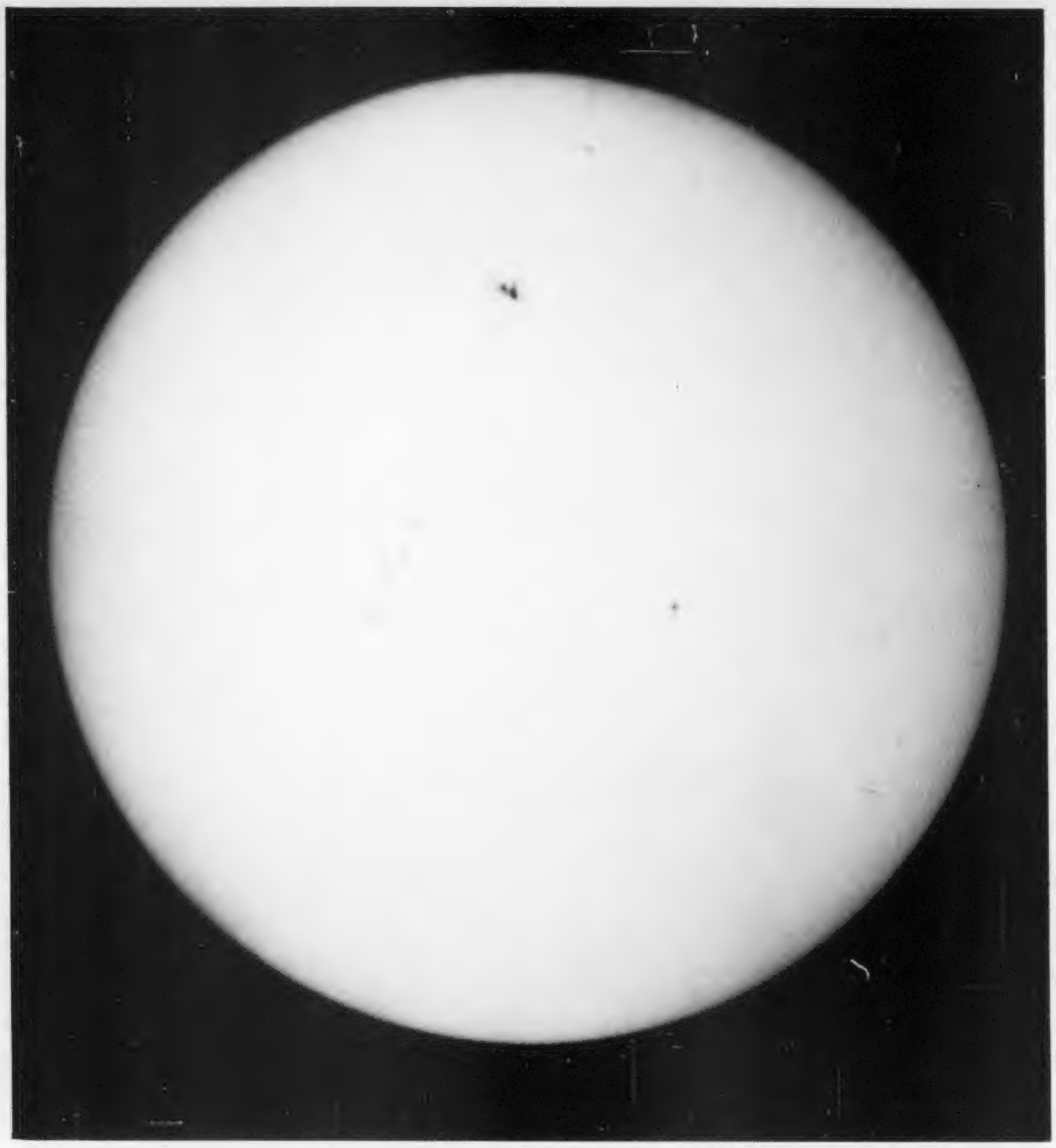
The Manned Maneuvering Unit enables astronauts to move around and work outside the Space Shuttle orbiter. The device fits on the astronauts backs and allows them to move around in space's weightless environment. Nitrogen gas jets controlled by the astronaut provide the directional movement.

haul. This ability to retrieve and repair satellites is unique to the Shuttle and should help reduce the cost of some future satellites by making extensive backup systems and extraordinary built-in reliability unnecessary.

The first such satellite repair mission is scheduled for *STS-13*. On February 14, 1980, the *Solar Maximum Mission* (*SMM*) satellite was launched by a Delta launch vehicle. SMM had a special grapple fixture on its side so that the manipulator arm on a future Shuttle could grab it for retrieval. Unfortunately, about nine months after launch, the satellite's attitude control system malfunctioned, and it began to slowly tumble. On *STS-13*, the Shuttle will rendezvous with the stricken satellite in space. Once the Orbiter is flying alongside the SMM, an astronaut will don a space suit and crawl out through an airlock into the cargo bay. He'll next put on a backpack-like maneuvering unit, fly over the satellite, match its rotation, and grab hold of it. Using the maneuvering unit, the astronaut will bring the spacecraft under control so one of the other crewmembers, working inside the Orbiter, can grab SMM with the manipulator arm. After the satellite is securely nestled in the cargo bay, the spacewalking astronaut will replace the faulty control system and several of the craft's scientific instruments and return it to active service.

The SMM repair, Space Telescope, and Spacelab missions mentioned here are only a sample of the varied flights and payloads we'll see with *Columbia, Challenger, Discovery,* and *Atlantis*. The fourth Shuttle flight carried an experiment designed to test pharmaceutical manufacturing in space. The results were most encouraging, so in a few years, we may even have commercial products that are made in space. The Space Shuttle is the key that will open many doors in space. With its new and unique capabilities such as in-space checkout of satellites, reduced launch costs, and satellite retrieval and repair, it offers many new possibilities for working in space. The first two decades of manned space flight were a period of exploration. With the reuseuable Space Shuttle and the Space Transportation System, the next should be a period of space exploitation. ■

Our Local Star



Even without a telescope, it is possible to see large sunspots. Conditions were just right on June 20, 1982, so the author of this article was treated to viewing this sunspot. At the same time, a NASM spacearium technician took this photograph with a 3½-inch aperture telescope using an objective solar filter. The large sunspot is about 63,000 km (39,150 mi.) in diameter. The smaller sunspots are roughly the same diameter as the Earth.

David DeVorkin
Associate Curator
Department of Space Science and Exploration, NASM

With the opening of NASM's new gallery on astronomy, *Stars: From Stonehenge to the Space Telescope,* here is a look at our very own star—the Sun.

Astronomers classify the Sun as a run-of-the-mill, yellowish dwarf star. But it has one distinguishing characteristic that separates it from all other stars and makes it unique: its distance from Earth. At an average distance of some 150 million kilometers (375 times the Moon's distance, or about 30,000 times the distance between Washington, D.C., and San Francisco), it is 250,000 times closer to us than the next nearest star in space.

The Sun's extreme proximity makes it an important object of study. The more astronomers know about the Sun, the more they can learn about other stars. From detailed observations from telescopes on the ground and in space, astronomers have determined that the Sun as well as other stars have: spots; a corona—an extended, extremely hot outer atmosphere; and solar wind—a constant outward flow of matter streaming into interplanetary space.

The Sun's importance to astronomy parallels its importance to our general well being. Without the Sun, we would not exist, neither would our planet Earth, nor our whole system of planets.

We live upon a small planet made up of material largely left over as our Sun was born billions of years ago. The matter that we eat and drink, the land we walk upon, the seas we sail, and the ocean of air we are blanketed under all came out of the same swirling cloud of hydrogen, helium, and celestial dust that contracted out of interstellar space so long ago to form our Sun.

But, can we really say what the Sun is? We have never seen its interior. Most of its energy is invisible to our eyes, because it is blocked either by our atmosphere or our eyes simply cannot detect it. When examined carefully, the Sun's many characteristics do reveal much about our star. We will, however, look only at sunspots.

Even without a telescope it is possible, if conditions are just right, to see large sunspots. The Sun has to be low in the sky, and it's helpful if there is much dust and water vapor in the atmosphere to further dim the Sun. Recently we were treated to viewing sunspots in this way. Even though there are records of sunspots being seen for centuries before Galileo's time, it is only with his telescopic observations around 1610 that general knowledge of their existence began. Galileo was able to demonstrate, after repeated observations covering many days and weeks, that sunspots were indeed dark localized objects on the surface of the Sun. He found that when they appeared close to the edge of the Sun, they traveled slowly. As they passed across the center of the disk, their daily angular motion increased. And as they approached the opposite edge of the disk, their angular rate of motion decreased once again. Galileo realized that this kind of behavior could only happen if the Sun was actually rotating, and the spots on its surface were rotating with it. This realization may seem rather mundane, but in Galileo's time, it was a revelation. The Sun had never before been thought to be a sphere in rotation or to have blemishes on its surface. Aristotle had taught the western world that the Sun was a pristine and perfect object in the heavens. Galileo permanently changed that picture.

Galileo demonstrated that telescopes could reveal details about celestial objects not visible to the unaided eye. As sunspots were viewed with improved telescopes, people speculated on what they could be. They came in almost any irregular shape and lasted for days, weeks, and sometimes several months. They came in groups or singularly. But what were they? Some thought that they were dark clouds floating above the solar surface; others believed them to be the tops of fiery solar volcanoes or even the debris from volcanic eruptions on the Sun. A popular theory, by astronomy professor Alexander Wilson, was that there were holes in the luminous shining solar atmosphere. He developed this theory between 1769 and 1774 at the University of Glasgow. Wilson thought that these holes revealed the dark solid surface of the Sun below the clouds.

Many people collected data on the number of spots that appeared on the Sun throughout the years. In some years, very few appeared; in others, many could be seen. Between 1826 and 1843, amateur astronomer Heinrich Schwabe found that the number of sunspots varied in a cycle of 11 years. The Sun was therefore not a perfectly constant star. Whatever the spots were, their quantity varied. And because they were darker than the rest of the Sun, the total output of energy from the Sun had to vary with the amount of spots on its surface.

Soon after Schwabe's work, the cycle of sunspots was found to be correlated with magnetic disturbances on Earth. Although this implied that sunspots possessed electrical or magnetic properties, there was no direct evidence of this until 1908 with George Ellery Hale's work. Hale used completely different techniques of observing sunspots than did Galileo, Wilson, or Schwabe. Schwabe's detection of the sunspot cycle and its correlation with geomagnetic phenomena excited interest in the behavior of spots, especially in finding the exact rate of solar rotation.

Until 1850, the use of sunspot motion to determine the Sun's rate of rotation yielded only rough results. This puzzling problem was solved by a wealthy English amateur astronomer, R. C. Carrington. After eight years of careful observation, he announced in 1863 that the Sun does not rotate as a solid. Spots close to the solar equator moved faster than those at higher latitudes. Also he found that the distribution in latitude of sunspots varied with the 11-year solar cycle. Spots early in the cycle were grouped at high latitudes. As the cycle matured, the mean latitude diminished. Carrington had no clear explanation for this behavior, but his careful statistics along with those of Schwabe's helped to establish the Sun as a complex body. Their work proved that the Sun was a variable star and that its outer portions probably were not solid.

During the years he was observing sunspots, Carrington carefully mapped what they looked like and faithfully reported any unusual occurrences. On September 1, 1859, he saw two intense patches of light dancing over a large spot that lasted no longer than five minutes. Carrington made this observation just when a strong magnetic storm was detected on geomagnetic instruments in London. He was the first to record a "solar flare," and it was quickly linked by some with the magnetic storm on Earth. In turn, this correlation strengthened the belief that both the sunspot and geomagnetic cycles were somehow related. To find out how, we return to George Ellery Hale, America's greatest entrepreneurial astronomer—founder of both the Yerkes and Mt. Wilson observatories.

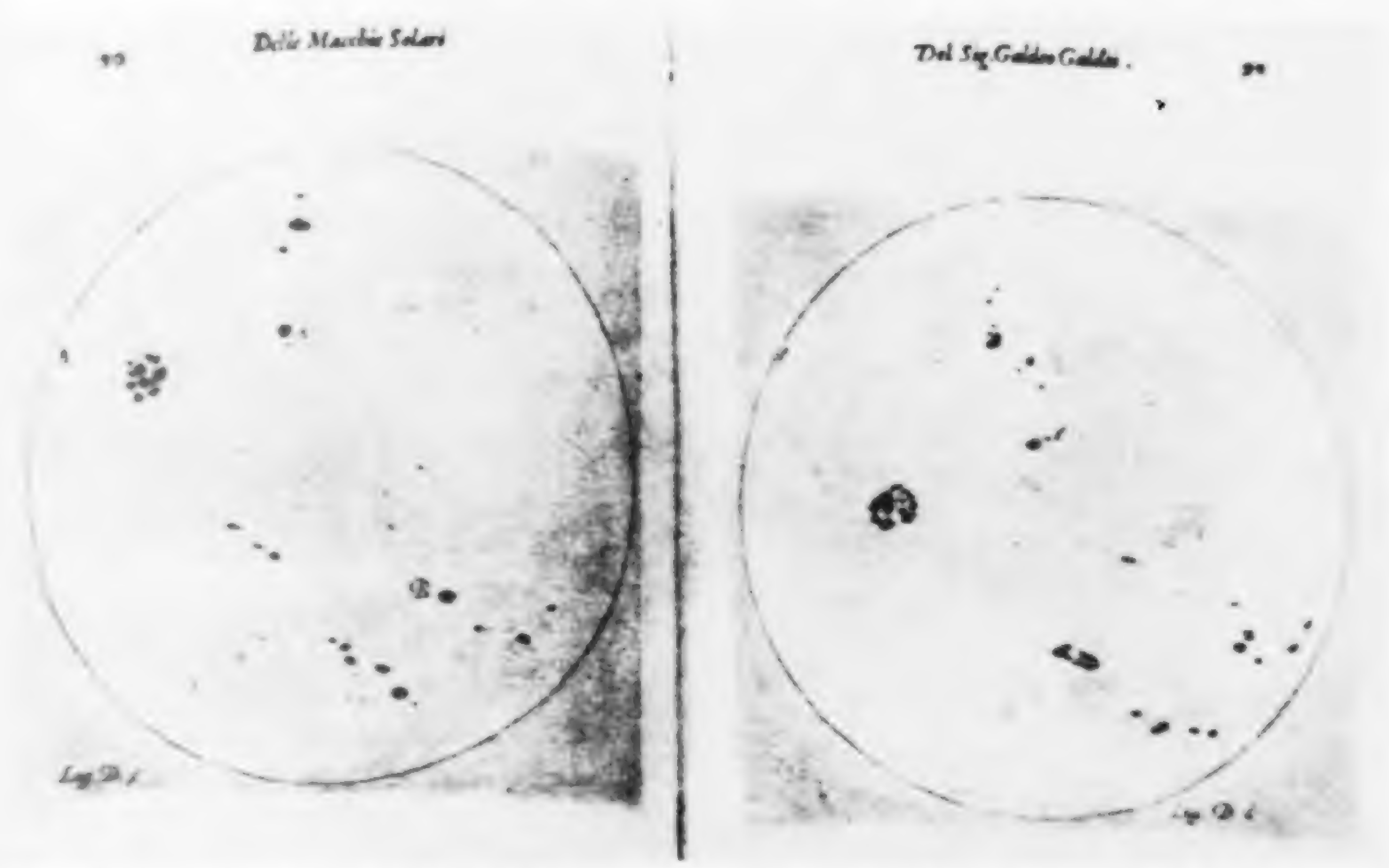
In 1908 Hale detected magnetic fields in sunspots by examining how single spectral lines from the solar surface appeared to be split into polarized pairs when the aperture of his Mt. Wilson spectroscope passed through a sunspot. He was not the first person to see this, but he was the first to argue that splitting of spectral lines in this way indicated the presence of a magnetic field. He knew that Dutch physicist Pieter Zeeman had produced split spectral lines in a laboratory by placing a hot gas in a strong magnetic field. Zeeman's study indicated that these lines were polarized, and Hale looked for the same polarization effects in the spot lines. He found them and thereby established the magnetic character of sunspots.

Thinking about sunspots this way has brought us to a better understanding of what the Sun is. The Sun's outer layers contain moving sheets, tubes, and layers of hot ionized gasses (called a "plasma" where atoms of the gas have lost one or more electrons and have thus become charged) that both produce and are influenced by magnetic fields. The differential motion, first detected by R.C. Carrington, can also cause the magnetic fields to twist about, concentrating the hot gasses into knots and causing explosive events such as flares.

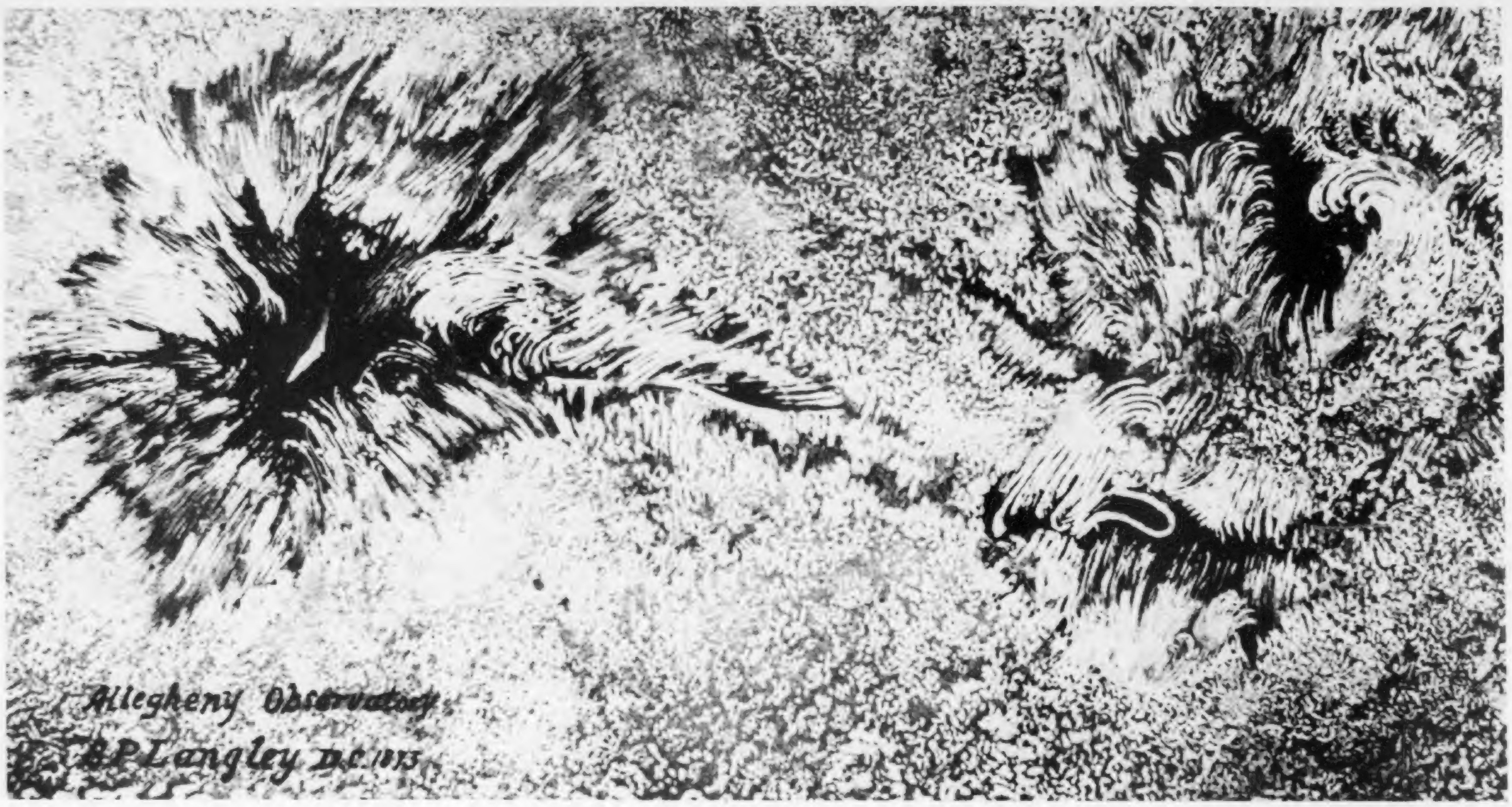
Since the 1940s and the development of sensitive radio techniques, we have gained clear evidence that the Sun radiates considerable energy in the form of radio waves. It came as no surprise that sunspots and solar flares were strong radio broadcasters and that, in fact, the high energy events causing spots and flares also could severely affect long-range radio communications on Earth.

Long-range radio transmission depends upon the reflection properties of a layer of ionized gas in the Earth's atmosphere called the ionosphere. Knowing these properties and what could aid or destroy them became important if long-range networks were to be maintained and made reliable.

During the 1930s, it was generally agreed that some portion of the high-energy range of solar radiation was the source of ionizing radiation that created and sustained the Earth's ionosphere. When scientists from both the Naval Research and Applied Physics laboratories began to use captured German V-2 rockets to explore the upper atmosphere just after World War II, they found that x-rays from the Sun were the most likely source of ionizing radiation. During the 1950s, the continuing study of the Sun's x-rays, made from brief Aerobee rocket flights, revealed that the Sun was a highly variable source of x-rays and that solar flares were extremely intense sources. Therefore the Sun and solar flares are crucially important for assessing the character of the Earth's ionosphere. Monitoring high-energy so-



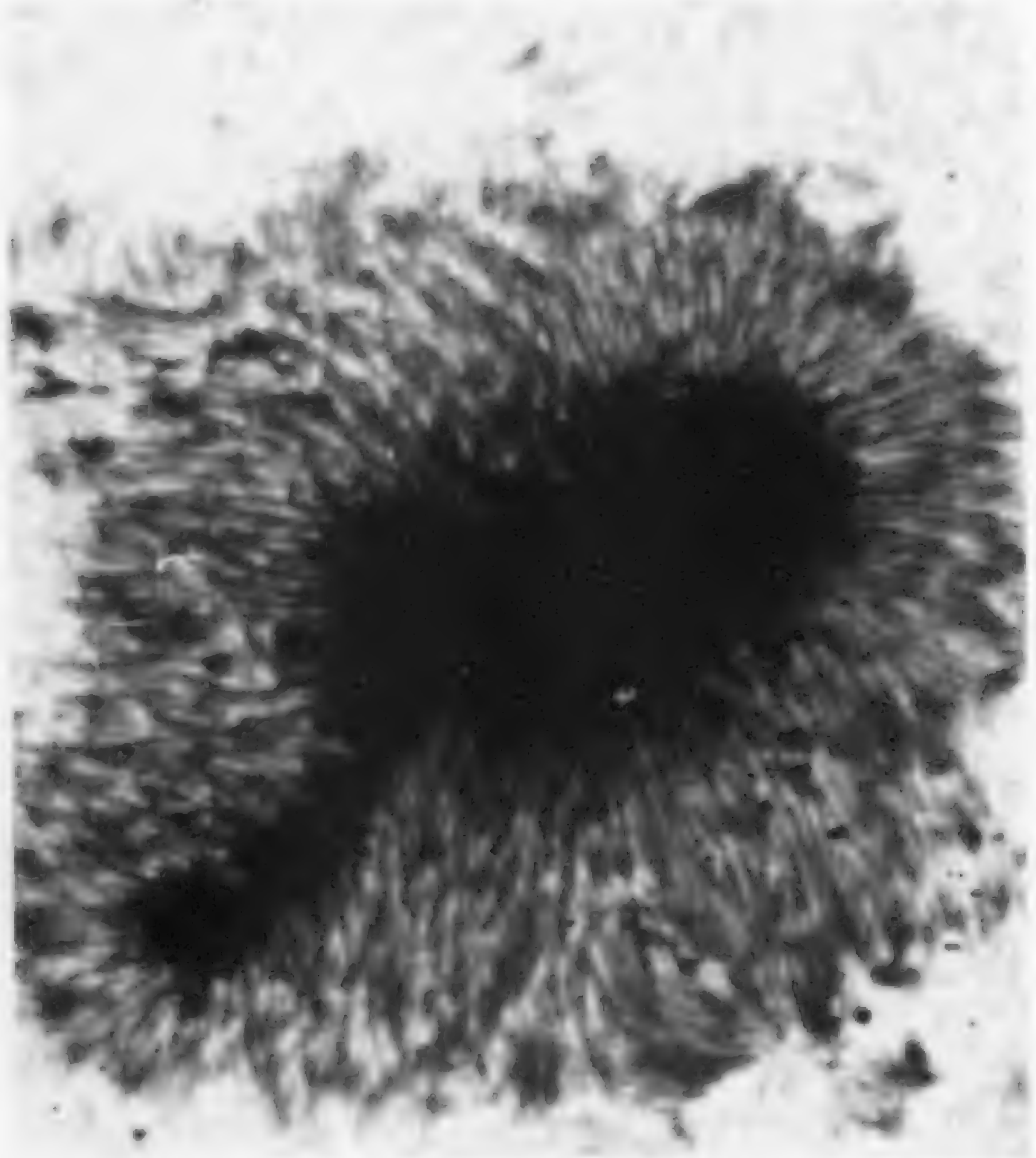
These drawings by Galileo in 1610 of the solar surface show the positions of sunspots on two different days. This is the first evidence that the Sun is a great sphere in rotation.



When Samuel Pierpont Langley, third Secretary of the Smithsonian Institution and founder of the Smithsonian Astrophysical Observatory, was at the Allegheny Observatory of the University of Pittsburgh, he developed his lifelong interest in studying the Sun. His remarkably detailed drawings of sunspots have been reproduced worldwide. Modern photographs confirm much of the detail captured by early visual observers such as Langley.

lar phenomena such as sunspots and solar flares thus became possible when satellites became available.

The Naval Research Laboratory initiated continuous monitoring of the high-energy part of the solar spectrum in 1960 when it flew its first SOLRAD satellite (Solar Radiation Satellite). In March 1962, the first OSO (Orbiting Solar Observatory) was launched by NASA, and it carried 13 separate experiments to examine the Sun in the far ultraviolet, the x-ray, and the gamma-ray regions of the spectrum. Early OSO satellites confirmed the multimillion degree temperatures of solar flares and gave us the first direct evidence that vast "holes" existed in the Sun's corona, through which high-energy particles streamed out into interplanetary space to create the solar wind. These phenomena were actually photographed in 1973 and 1974 by highly refined solar telescopes flown in a large cannister called the Apollo Telescope Mount aboard Skylab. The ATM was our first manned solar observatory in space.



In the late 1950s, a group of astronomers at Princeton University, led by Martin Schwarzschild, sent a 30-cm (12-in.) reflecting telescope to an altitude of 24,385 m (80,000 ft.) by balloon to capture these very high resolution images of sunspots and the solar surface granulation.

The latest solar satellite—the Solar Maximum Mission—was launched on February 14, 1980, during a period when sunspot activity was at its peak. Its goal was the detailed study of the active Sun. Another goal was to study flares in the ultraviolet, x-ray, and gamma-ray ranges and to determine the effects of these flare events on the structure and character of the solar corona. Soon after its launch, a unit of the spacecraft that controlled its ability to point at the Sun failed. The satellite was shut down but continues to orbit the Earth.

This satellite, which represents an investment of some 75 million dollars, might be given a second lease on life. It was designed to be serviced from orbit by the Space Shuttle and might well be saved by a Shuttle repair flight in the future.

This brief account has chronicled several milestones in observing the nature of the active Sun. Much, necessarily, has been neglected, such as the great tradition of ground-based observations through the late 19th and 20th centuries. Also neglected were the many theoretical studies of the structure and energy source of the Sun, especially the symbiotic relationship between theoretical astrophysics and modern physics that has been largely responsible for providing our modern physical understanding of the great globe of glowing gas that is our star, the Sun. ■

To learn more about these areas of solar studies, use the appended short list of readings (which are in order from easiest to most difficult).

Selected Readings:

- A collection of descriptive essays on the Sun and its importance for life on Earth is provided in:
  Fire of Life: The Smithsonian Book of the Sun. Washington, D.C.: Smithsonian Institution Press, 1981.
- An excellent and largely non-technical review of the results of the Skylab Apollo Telescope Mount, which also includes a historical introduction:
  Eddy, John A., *A New Sun: The Solar Results from Skylab*. Washington, D.C.: NASA, 1979.
- A revision of a classic introductory descriptive text on solar physics and the general study of the Sun:
  Menzel, Donald H., *Our Sun*. Boston, Mass.: Harvard University Press, 1959.
- An excellent historical introduction to a collection of classic papers on the Sun:
  A.J. Meadows, *Early Solar Physics*. Oxford, England: Oxford University Press, 1970.

Different Views of Earth and Sky

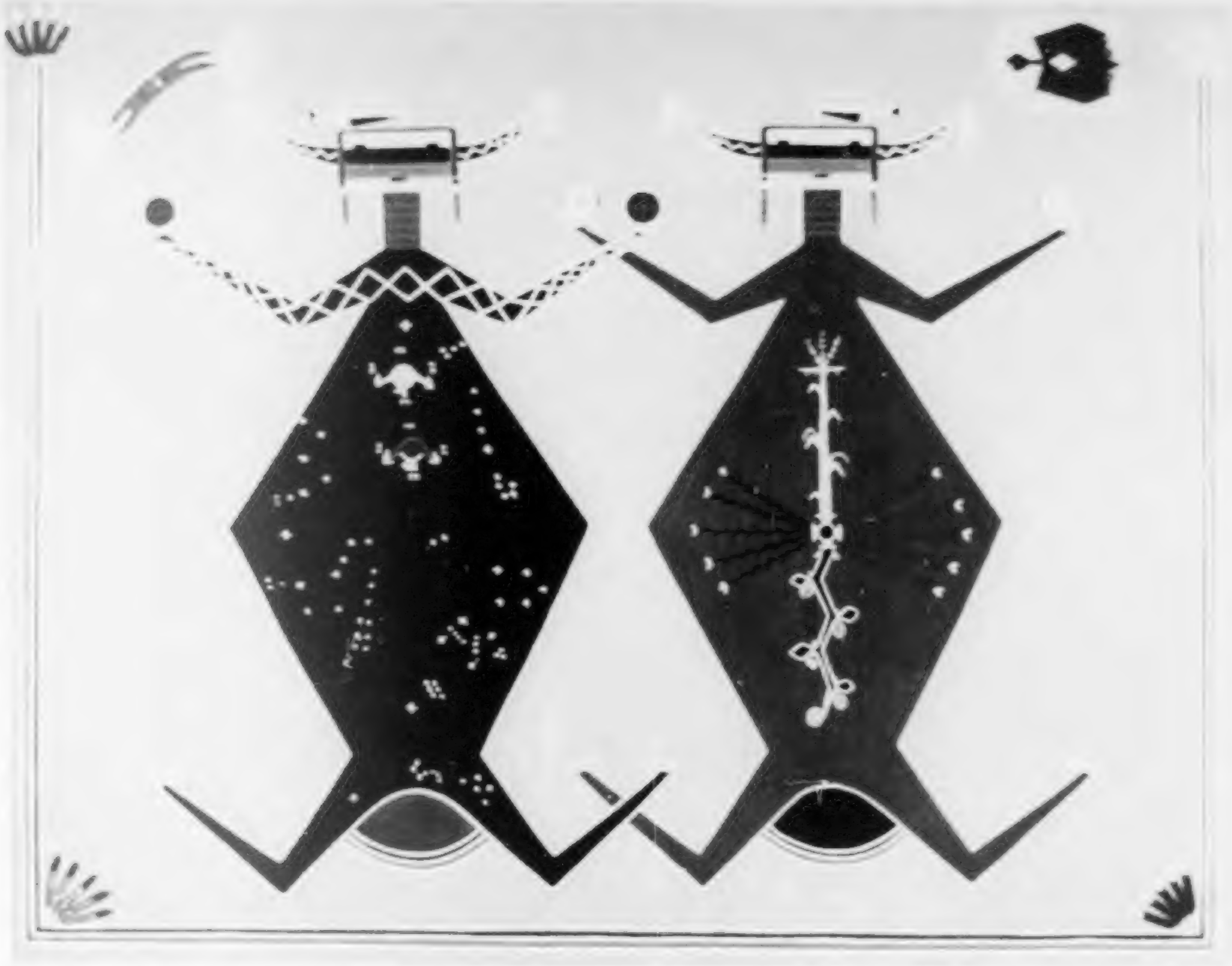


Figure 1: In all Navajo dry (sand) paintings of Mother Earth/Father Sky, the border surrounding them represents a rainbow and is open at the East (top).

Von Del Chamberlain
Astronomer
Department of Space Science and Exploration, NASM

Traditional views of Earth and Sky are well represented by the Native American concept of Mother Earth and Father Sky, in which people, as well as other forms of life, are thought to have originated from Earth itself and to have been continually nourished by both Earth and Sky. Many things we observe in nature lend credence to this idea: we must have warmth and light from the Sun; life requires moisture from the sky; we live and grow by consuming what springs up from the ground; all seasonal events, including the renewal of life each year, have obvious relationships with Earth and Sky. The Navajo sand painting (fig. 1) portrays these ideas: plants grow out of Mother Earth; the Sun, Moon, stars, and Milky Way (cross-hatching across arms and shoulders) adorn Father Sky; both join arms and legs as Earth and Sky come together at the horizon. The pair are protected by the surrounding rainbow, which is seen in nature arching from Earth to Sky when Father Sky has shed life-giving tears upon his mate. Similar sets of concepts are found in many other cultures. Greek mythology, for example, portrays Gaea (Mother Earth) born out of Chaos. Then Gaea bore Uranus (Sky) and from the union of Earth and Sky descended other deities and eventually Man.

Another concept, from the Skidi band of the Pawnee of the Great Plains, views the sky as the dome ceiling of the lodge that the gods and all their creations live in. These prairie people even patterned their earthly homes after this idea: they identified the domed roofs of their lodges with the sky, their warm fires with the Sun, and other features of the lodges with stellar deities. Their houses were tiny models of the universe, and they were constantly reminded of their belief that they belonged to the sky.

Our concepts of ourselves have always provided foundations for our motivations. The Mother Earth/Father Sky and celestial house ideas resulted in deep feelings of unity with all of nature, and people who lived with these ideas cherished life-styles that involved direct contact with the ground and its products. Hunting, gathering, and agriculture were essential and desired activities, and there was little inclination for changes in the basic patterns of existence.

Most of us have grown up without these concepts. Throughout time we have learned the thrill of discovery, and this motivation has brought increased knowledge, which has resulted in the technologies we know today. The same discoveries that brought machines have also changed our perceptions of ourselves and the world around us. Our lives are filled with man-made devices: sidewalks, roads, and vehicles; temperature controls, calculators, newsprint, television, film, and artificial sounds. We largely create and control our environment, and we have instruments that reveal aspects of the world our senses alone do not perceive. We think about atoms, molecules, quasars, and black holes. Indeed, we tend to think of ourselves as separate from the rest of nature rather than intimate parts of it.

Taken at Kitt Peak National Observatory, on the Papago Indian Reservation, near Tucson, Arizona, the photograph in figure 2 illustrates how different concepts can be. On the right is a dome-shaped mountain that, according to Papago tradition, represents the place of emergence of Man from Mother Earth—in a sense the center of the universe. On the left is a dome-shaped housing for a telescope. With such instruments astronomers look outward in hopes of being able to detect the edge of the universe. In modern cosmology a universal center has no meaning.

Different views continue to come to us as knowledge brings new experiences and opens our vision to new possibilities. The more ways we can study an object, the more thoroughly we understand and appreciate it. For most of human history we were bound to the surface of the Earth and thought that it was at the center of the universe. Then observation and theory convinced us that we were passengers on a planet orbiting a star. This new concept allowed us, to visualize Earth from afar: it gave us the perspective espoused by Socrates whose ideas have been paraphrased:

> Man must rise above the earth—

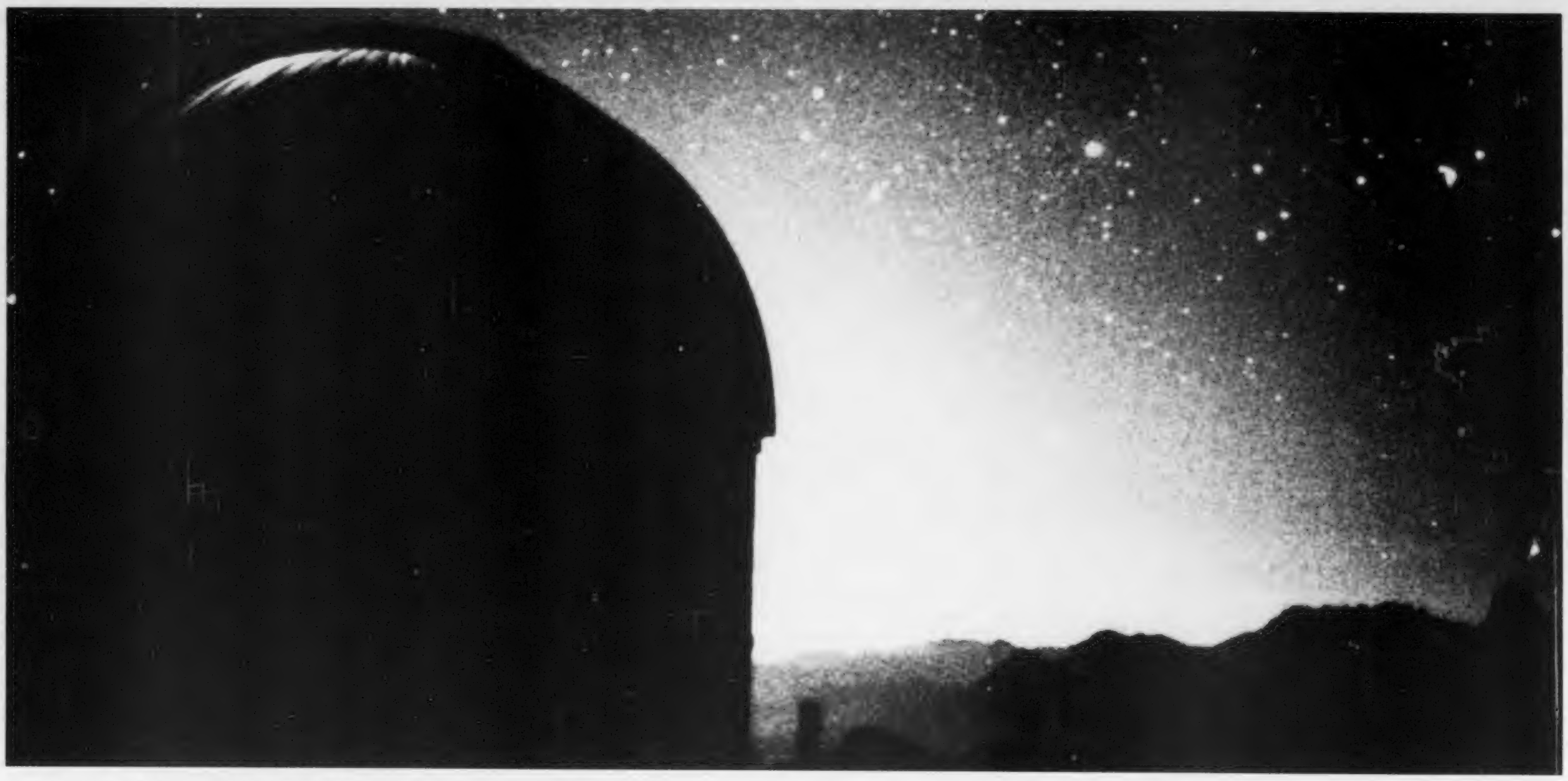


Figure 2: A dome at Kitt Peak National Observatory (left) and Boboquivari Peak (extreme right, below the lowest bright star), the legendary center of the Papago Universe, is set against a starry sky.

Figure 3: This picture of a crescent-shaped Earth and Moon—the first of its kind ever taken by a spacecraft—was recorded September 18, 1977, by NASA's Voyager 1 when it was 11.66 million km (7.25 million mi.) from Earth.

> To the top of the atmosphere and beyond.
> For only thus will he fully understand
> The world in which he lives.

We learned many ways to study the Earth in more detail without ever leaving it. With microscopes we learned its mineral structures and eventually its molecular and atomic forms. What seemed solid was actually space, and the boundaries between matter and energy dissolved. Eventually we literally did what Socrates encouraged. At last we rose upward, at first into the air and eventually into space, to look down on our world. What we had known from reason for centuries became true in experience, and we learned the significance of the words of British astronomer Sir Fred Hoyle written in 1948:

> Once a photograph of the Earth, taken from the outside, is available—once the sheer isolation of the Earth becomes plain—a new idea as powerful as any in history will be let loose.

Now we have looked at clouds from both sides, and we have seen our planet through the eyes of probes headed toward the outer parts of the Solar System. Figure 3 shows our world, together with its satellite the Moon, from more than seven million miles away. What is most impressive about this view is the *lack* of visible detail: it resembles images of other planets seen through earthbound telescopes, reminding us of how small and delicate our planet really is in the vast universe. The astronauts seemed most impressed not by what they saw looking toward the stars but by how they felt looking back at the blue planet. In 1968, when three Apollo 8 astronauts orbited the Moon while the rest of us celebrated Christmas on Earth, writer Archibald MacLeish attempted to put such feelings into words:

> To see the earth as it truly is, small and blue and beautiful in that eternal silence where it floats, Is to see ourselves as riders on the earth together, Brothers on that bright loveliness in the eternal cold—Brothers who know now they are truly brothers.

It is this combination of views, from the surface and from beyond, with the microscope and the telephoto lens, that gives us the best understanding and feeling for our planet.

A most impressive pair of pictures (fig. 4) results from the different viewpoints available to us now. On the left is a view from orbit looking down on the U.S. on a clear night. On the right is a view resembling what you would see from an unpopulated place on Earth looking up on a clear night. The one that people have enjoyed from their beginnings on this planet has produced the motivations and questions that led to the possibility of the other. A few questions are in order concerning both pictures. What would we have seen if we had been able to look down from orbit a century ago? What will we see a century from now? What was the common view of the night sky a century ago? What is

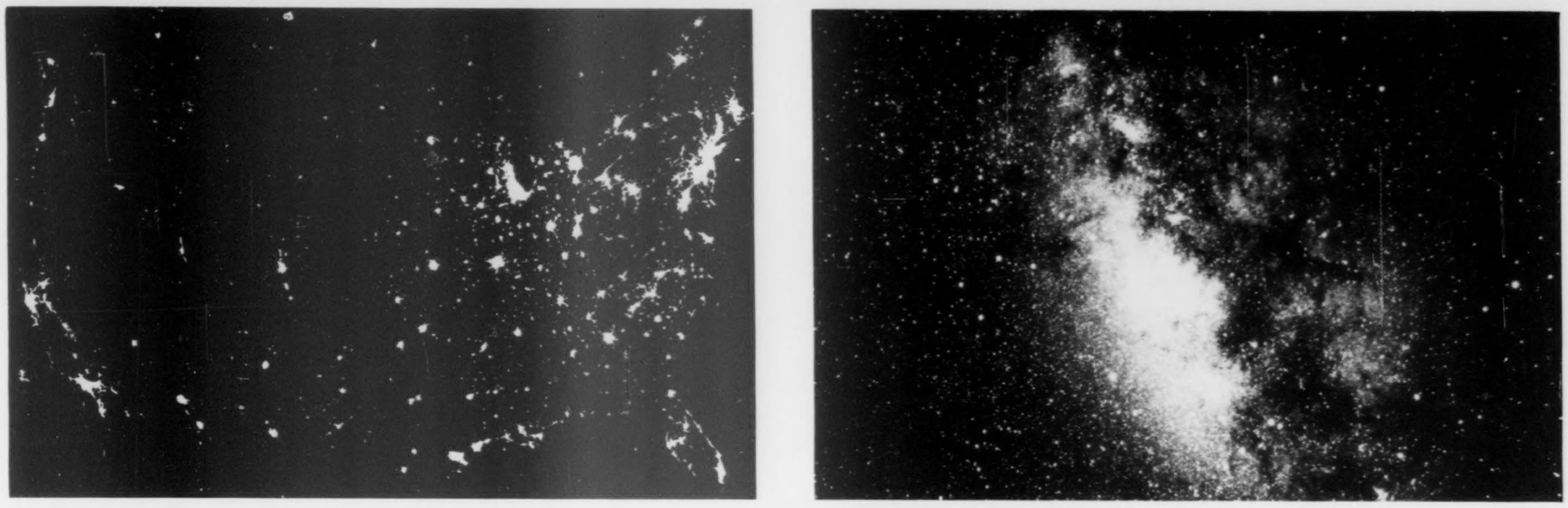


Figure 4: This combination of views, from the surface and from beyond, gives us the best understanding and feeling for our planet. The original satellite photograph of "Looking Down on a Clear Night" (left) is a composite made by the U.S. Air Force. "Star Clouds and Dust in the Milky Way Looking toward the Galactic Center" (right), is a photograph taken by David L. Talent.

it now? What will it be in another 100 years? Where are the really dark places on the continent where we can still see the pristine star-studded sky?

How long has it been since *you* last saw the stars on a clear, moonless night, from the country where the Milky Way was clearly visible? City life together with busy schedules tend to take away even the incentive for such experiences. What have we lost? The gleaming lights of the U.S. at night, which deny us the view of the stars, reveal the greatness of our country—the technological capability we have achieved and the around-the-clock activity that keeps us great. Because of all these things and more, most of us have given up the experience of seeing the majestic starry sky. Our technologies that make it possible to see the Earth whole and to travel around it quickly have made us, in some ways, less sensitive to the fact of our true intimate relationships with soil and sunlight. But in other ways we have gained the possibility, if we will but pause to realize it, for greater sensitivity to such things. We now can see more deeply than ever before into the workings of the natural world.

And when we do look into the heavens, we see something quite different than people before us saw. Our knowledge about the stars has forever changed us. Now we reason, "since the Sun is only one common star and since we are here on this one planet, there might well be other worlds with intelligent creatures looking out and wondering." We now know that the stars are energy and element factories. As stars flood surrounding space with energy that could make places like Earth possible, their thermonuclear interior processes build up complex atomic elements from simpler ones. It is these star-bred elements like carbon, oxygen, nitrogen, iron, and others that make rocky planets like Earth possible. Long ago stars made these elements, then spewed them back into space to enrich the interstellar clouds from which stars like the Sun and planets like Earth formed. Around us we see recycled stardust now in the form of rocks, rivers, trees, animals, and even people. The astronomer Harlow Shapley expressed this knowledge when he said, "We are brothers to the boulders and cousins to the stars." With these things in mind it has been said that people, after all, are atoms ways of knowing atoms, stars ways of knowing stars, and the universe's way of contemplating itself. It now seems likely that we are only one example of intelligence capable of conceiving such things, and the awareness of that possibility has prepared us for potential entry into interstellar society.

It is interesting to note how different views—of the past as well as the present—can often blend to give us the best perspective we have ever enjoyed. Today we would do well to re-examine some past ideas. Modern astrophysics does not negate the traditional idea of Mother Earth and Father Sky at all: we can simply reinterpret it. Because stars are element and energy factories and no one could possibly live without the Earth, we can feel quite comfortable with the words of a Native American poet:

> Oh our Mother the Earth, oh our Father the Sky
> Your children are we, and with tired backs
> We bring you the gifts that you love.
> Then weave for us a garment of brightness;
> May the wrap be the white light of morning,
> May the weft be the red light of evening,
> May the fringes be the falling rain,
> May the border be the standing rainbow.
> Thus weave for us a garment of brightness
> That we may walk fittingly where birds sing,
> That we may walk fittingly where grass is green,
> Oh our Mother the Earth, oh our Father the Sky!

And from the Pawnee we can abstract the idea that the sky, the universe, is indeed our real home. We should think of ourselves as citizens of the universe, recognizing our potential in that citizenry, rather than restricting our self-image to occupancy on the planet's surface. Perhaps such a concept would help us see beyond our earthly problems to perpetuate our existence for exploration of our interstellar possibilities.

Our different views, throughout human history on planet Earth, have brought us many contradictions, but tend, overall, to make it possible for each of us to see ourselves more clearly in relationship to the world in which we live. Now it requires planning and effort to go out into the night and enjoy the inspiration of starry skies, but when we do, we can more fully appreciate both ourselves and the rest of the universe. We can be appropriately intelligent and emotional about Earth and Sky. With Louise Weber we can say:

> I may inhabit worlds in time to come
> Of finer substance, born of farther suns;
> A greater glory I may one day see,
> But oh, today, dear Earth, how I love thee!

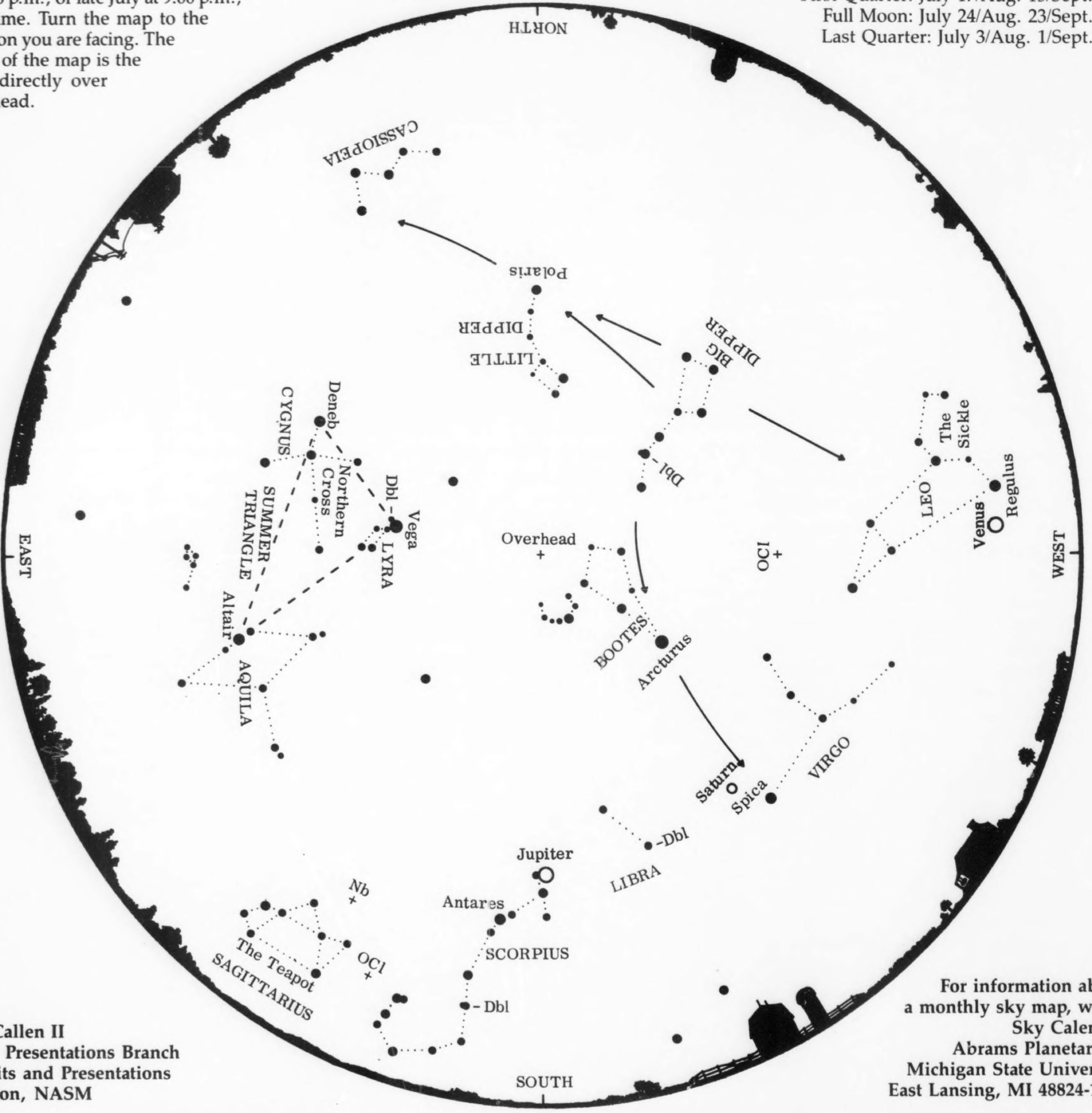
Suggested Readings:

- Chamberlain, Von Del. *When Stars Came Down to Earth: Cosmology of the Skidi Pawnee Indians of North America*. Los Altos, Calif.: Ballena Press/ Center for Archaeoastronomy, 1982.
- MacLeish, Archibald. "Riders on Earth Together: "Brothers in Eternal Cold." *New York Times* December 25, 1968.

Sky Map
Summer 1983

This circle represents the night sky as it appears in late June at 11:00 p.m., early July at 10:00 p.m., or late July at 9:00 p.m., local time. Turn the map to the direction you are facing. The center of the map is the point directly over your head.

Phases of the Moon
New Moon: July 10/Aug. 8/Sept. 7
First Quarter: July 17/Aug. 15/Sept. 13
Full Moon: July 24/Aug. 23/Sept. 22
Last Quarter: July 3/Aug. 1/Sept. 29


NORTH
CASSIOPEIA
Polaris
LITTLE DIPPER
BIG DIPPER
Dbl
The Sickle
LEO
Regulus
Venus
OC1
WEST
Overhead
BOOTES
Arcturus
VIRGO
Saturn
Spica
Dbl
LIBRA
Jupiter
Antares
SCORPIUS
Dbl
Nb
OC1
The Teapot
SAGITTARIUS
SOUTH
EAST
Altair
AQUILA
SUMMER TRIANGLE
CYGNUS
Deneb
Northern Cross
Dbl
Vega
LYRA

T.H. Callen II
Chief, Presentations Branch
Exhibits and Presentations
Division, NASM

For information about
a monthly sky map, write:
Sky Calendar
Abrams Planetarium
Michigan State University
East Lansing, MI 48824-1324

Summer's skies, like those of winter, give us a bumper crop of bright stars including, at chart time in order of apparent magnitude, Arcturus, Vega, Altair, Spica, Antares, Deneb, and Regulus. (Recall that a star's apparent magnitude is how bright it appears to the eye.) Of these, only Regulus is not among the 20 brightest stars in the heavens. Compared to the relative closeness of our day star, the Sun, all appear over a billion times fainter in the night sky. We can, however, put the Sun into its proper place by using what is known as a star's absolute magnitude, how a star would look if placed at a set distance. This distance is 10 parsecs, about 32.6 light years, which is over 2½ million times farther than the Earth and Sun are from each other.

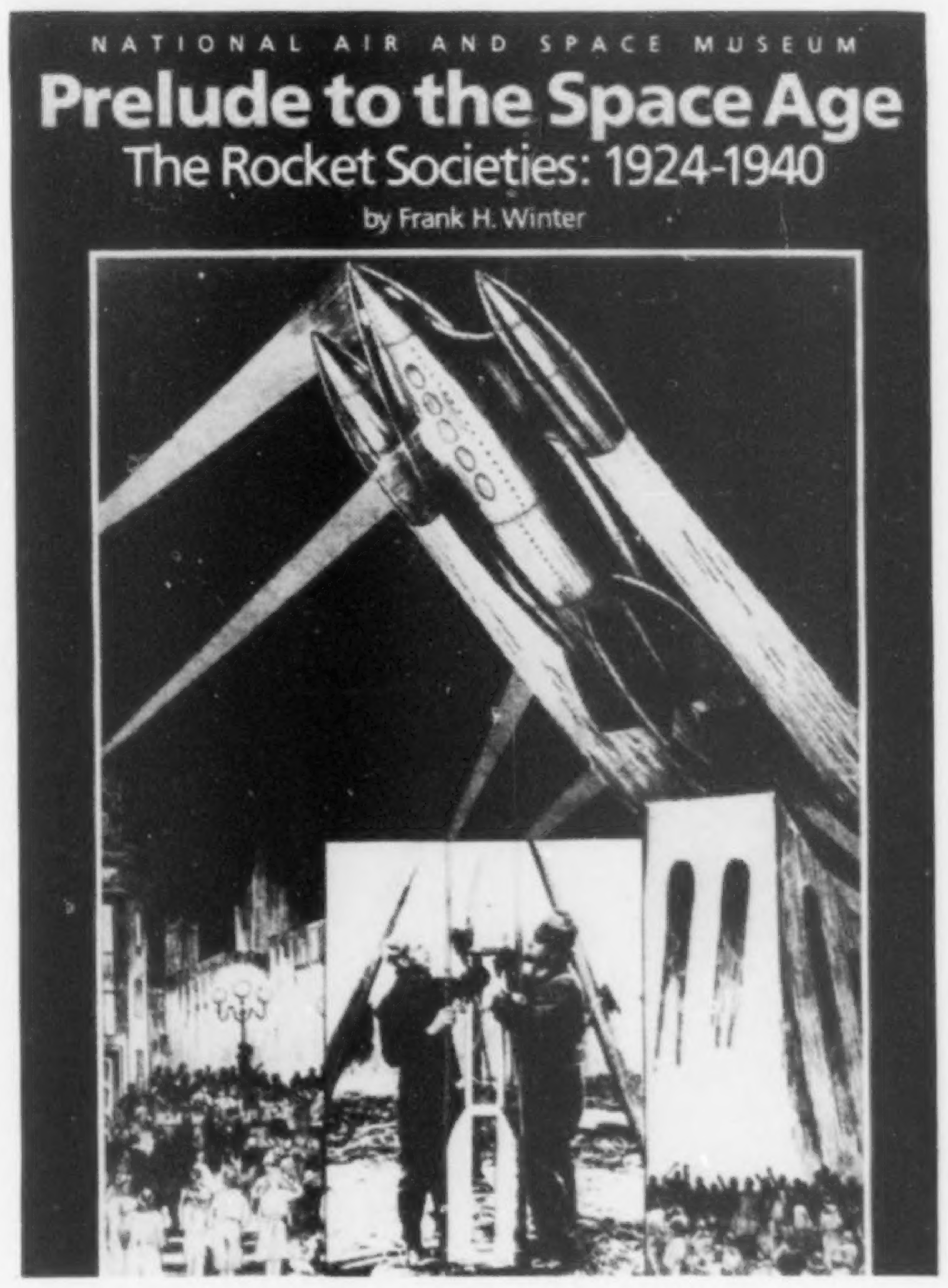
At this fixed distance, these stars are brighter than the Sun by the following amounts: Deneb (59,736x's), Antares (9467x's), Spica (1804x's), Regulus (164x's), Arcturus (114x's), Vega (54x's), and Altair (11x's). In this way we can see that the spectral type of the star, its classification according to the characteristics of its spectrum (the array of colors seen when its light is passed through a prism), is what determines its ordering. A very luminous supergiant like Deneb easily overpowers average stars such as Vega and our Sun. What happens when you compare a star's apparent and absolute brightness to each other?

Let's use Antares as an example. To the naked eye, it appears to have an apparent magnitude of +0.92, while at 10 parsecs it *increases* to an absolute magnitude of −5.1. Remember that "−" magnitudes are brighter than "+" magnitudes. Antares is 160 parsecs (520 light years) away, so it obviously became brighter because we had to move it 16 times closer (to 10 parsecs away) to find its absolute magnitude. Can you figure out the same for the other stars? To help you get started, the Sun gets 4¼ trillion times fainter when moved to our set distance for comparison.

Books from NASM Authors

Prelude to the Space Age: The Rocket Societies 1924-1940
by Frank H. Winter. 250 pages, 51 b&w illus. (8½ × 11) $15.00 (April 1983)

The Space Age began in 1957 with the launch of Sputnik 1, but the roots of this era date to the 1920s and 1930s when the first books appeared on the subject and the first societies were organized to promote the cause of space flight. These societies, in the U.S., Germany, USSR, England, and other countries, conducted some of the first liquid fuel rocket experiments, trained some of the future space rocket builders (such as Wernher von Braun), and made the world space conscious. Frank Winter documents the formative years of these groups in this book.


NATIONAL AIR AND SPACE MUSEUM
Prelude to the Space Age
The Rocket Societies: 1924-1940
by Frank H. Winter

Milestones of Flight: Pathfinders in the Sky
48 pages, 30 b&w, 25 color illus., (6 × 9) $2.75 (June 1983)

The Museum's renowned milestones of flight collection is highlighted in this booklet. The stories of these treasured artifacts, the people and organizations surrounding the development of the history-making "firsts"—from the Wright brothers 1903 Flyer to the Viking Lander, from Lindbergh's *Spirit of St. Louis* to the Apollo 11 spacecraft—are complemented by historical and exhibition photos. This is the fourth in the series of exhibition booklets and is also an introduction to the Museum's central gallery.

Red Phoenix: The Rise of Soviet Air Power 1941-1945
by Von Hardesty. 288 pages, 150 b&w illus., 8 maps. (8 × 10) $22.50

Von Hardesty chronicles the full story of the epic four-year conflict between the Soviet Air Force and Hitler's Luftwaffe. The book includes a definitive bibliography, the most complete compilation to date of English and Russian titles dealing with the air war on the eastern front.

Missiles, Rockets, and Spacecraft of The National Air and Space Museum
compiled by Gregory P. Kennedy. 170 pages, 118 b&w illus. (8½ × 11) $4.00 (June 1983)

NASM has in its collection the most famous astronautical objects in history including the Apollo 11 spacecraft, the Lunar Module, Skylab, Goddard's 1926 rocket, and Pioneer 10. This revised comprehensive catalog describes the astronautical artifacts on display in the Museum with historical information, photographs, and data blocks.

Vengeance Weapon 2: The V-2 Guided Missile
by Gregory P. Kennedy. 88 pages, 118 b&w illus., (8½ × 11) $9.95 (late spring 1983)

Kennedy chronicles the development and use of the V-2, from its origins to its use in post-war rocket research programs. A special appendix "peels away" the missile's skin to provide a detailed look at the V-2's inner mechanisms. Also included are many previously unpublished illustrations.

The Dragon's Teeth? The Creation of U.S. Air Power for World War II
by Benjamin S. Kelsey. 148 pages, 70 b&w illus. (6 × 9) $17.50

Kelsey describes how Americans cast down the "dragon" of anti-militarism that prevailed in the 1920s and 1930s to amass the mighty air fleet that crushed the Axis powers. Brigadier General Kelsey, USAF (Ret.) actively participated in this expansion of U.S. air power.

Index Volume 6, 1982-1983

This index is for Volume 6 of *Air & Space* (four issues published during the 1982-1983 school year). The four issues, beginning in the Fall of 1982, are: Fall, Winter, Spring, and Summer.

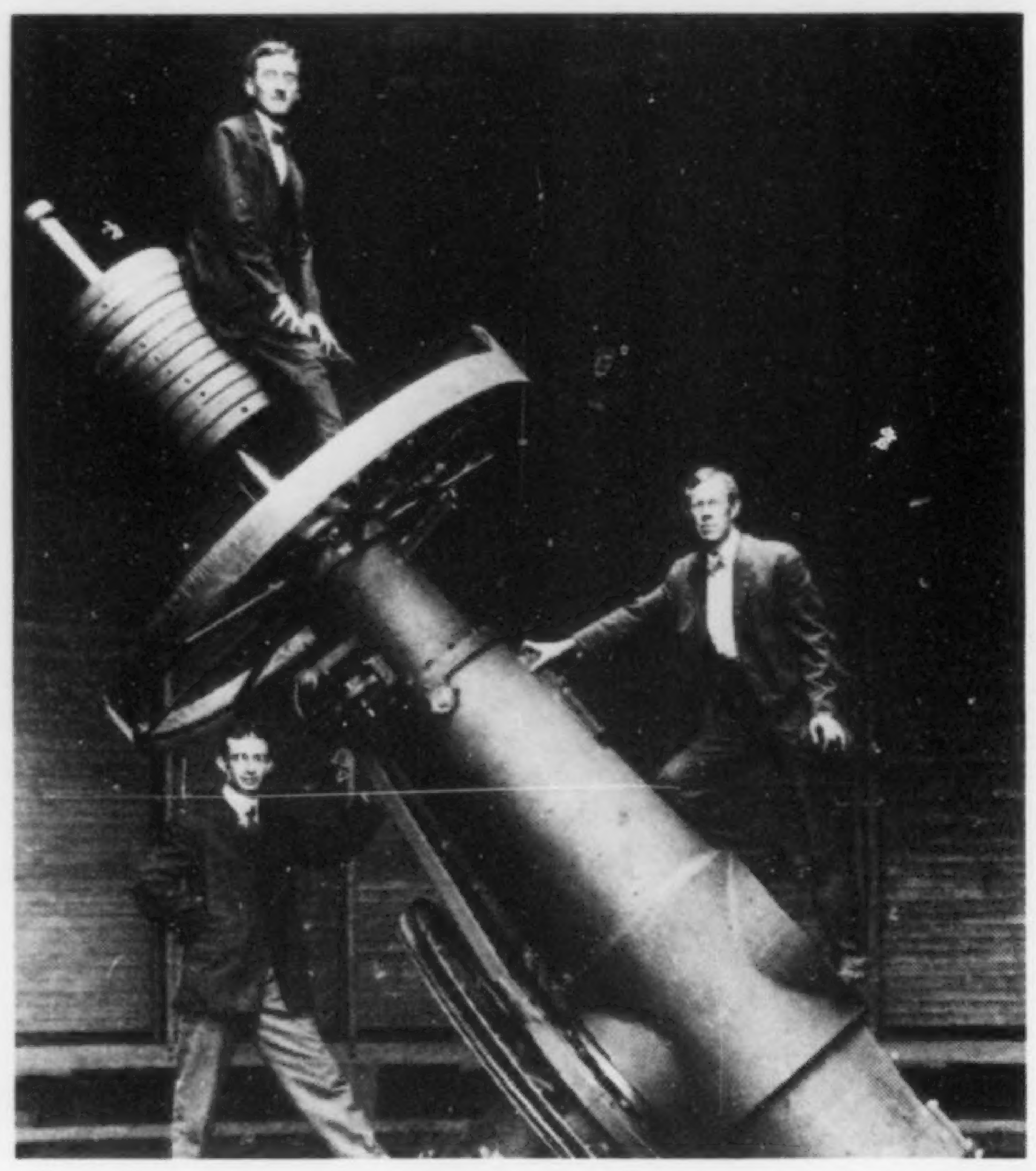
Back issues of *Air & Space* are available on microfiche or photocopy through University Microfilms International, Inc., 300 N. Zeeb Road, Ann Arbor, Michigan 48106.

Aerial Navigation—Then and Now. Summer, p. 3.
Blacks in Commerical Aviation. Winter, p. 16.
Briefing. Each issue, p. 2.
Decision to Go to the Moon, The. Fall, p. 5.
Early Airlines—1919-1929, The. Winter, p. 3.
Energy From Space—A Goal For Space Industrialization. Spring, p. 15.
First Four Decades of Jet Aviation, The. Winter, p. 13.
Flight Attendants. Winter, p. 18.
Francis Arcier, Designer of Aircraft. Spring, p. 3.
Great Days of the Airmail, The. Winter, p. 6.
Major Unmanned Space Firsts of the United States and the USSR. Fall, p. 12.
Moonwatch Era Ends, The. Fall, p. 3.
Ocean Conquest: The Thoroughbred Propeller Airliner. Winter, p. 10.
Our Local Star. Summer, p. 12.
Project Mercury—Before it Became Project Mercury. Spring, p. 8.
Reflections of an Apollo 11 Astronaut. Fall, p. 7.
Sky Map. Fall, p. 17; Winter, p. 19; Spring and Summer, p. 18.
Smoke Job. Summer, p. 7.
Space Art: 100 Years of Space Exploration. Fall, p. 14.
Space Flight—A New Perspective. Summer, p. 9.
Space Station: The Next Step In Space? Spring, p. 12.
Unmanned Spacecraft: 25 Years Listening and Learning. Fall, p. 11.
Wings on Dreams. Spring, p. 6.

Major Exhibition Gallery on Stars to Open at NASM June 9, 1983

Stars: From Stonehenge to the Space Telescope

The *Stars* gallery will take visitors on a tour of the known universe—from ancient times to the present—and provide a look at upcoming plans for futher exploration. A major section of the gallery will focus on the Sun. Also included is a look at the Milky Way Galaxy from inside and out. Artifacts for the gallery include Uhuru, the first U.S. x-ray astronomy satellite; a full-scale engineering model of the International Ultraviolet Explorer satellite-observatory; the orbiting astronomical observatory Copernicus; and a 1:5 scale model of the Space Telescope, which will be launched from the Space Shuttle in 1985. Also exhibited is a section of the back-up Apollo Telescope Mount used on Skylab in the 1970s.



Stars and Planets Symposium

August 22-24, 1983

NASM's Stars and Planets Symposium is intended to provide secondary level science educators, science curriculum specialists, and administrators who are concerned with the quality of science education in schools today, with an awareness of available national resources.

The symposium will include lectures, discussions, activities, tours, and field trips that will enhance participants' abilities to communicate with and prepare students for an increasingly technological society.

For more information, write:
Janet K. Wolfe
Chief, Education Services Division
National Air and Space Museum
Washington, D.C. 20560

National Air and Space Museum
Smithsonian Institution
Washington, DC 20560
Room P-700

Non-Profit Org.
U.S. Postage
Paid
Permit #3361
Baltimore, Md.

JOYCE BROWN 800455
SERIALS DEPARTMENT
UNIV. MICROFILMS INTERNATIONAL
300 N. ZEEB ROAD
ANN ARBOR, MI 48106